

**EARTH SCIENCE INVENTORY
AND EVALUATION OF
MONO CLIFFS
PROVINCIAL PARK**

1991



Ontario

**Ministry of
Natural
Resources**

**AN EARTH SCIENCE INVENTORY AND EVALUATION OF
MONO CLIFFS PROVINCIAL PARK**

P.S.G. KOR
1991

**ONTARIO HERITAGE FOUNDATION
NIAGARA ESCARPMENT HERITAGE PROTECTION AND
LAND STEWARDSHIP PROGRAM**

**ONTARIO MINISTRY OF NATURAL RESOURCES
CENTRAL REGION, AURORA**



Ministry of
Natural
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This report is one of a series of geological and ecological inventories of significant natural areas of the Niagara Escarpment, supported by the Ontario Heritage Foundation (Niagara Escarpment Heritage Protection and Land Stewardship Program) and the Ontario Ministry of Natural Resources.

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Reference copies of this report are available in the offices of Central Region OMNR, 50 Bloomington Road West, Aurora, Ontario L4G 3G8, Telephone (416) 841-9341 and the Natural Resources Library, 5th Floor, 90 Sheppard Avenue East, North York, Ontario M2N 3A1. Copies have been sent to university libraries in southern Ontario.

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PREFACE

The Mono Cliffs Provincial Park Master Plan (1974) recommended a number of "Natural Zones" for the protection of geological and ecological values in the newly established park. These included most of the wooded areas of the uplands above the escarpment, the escarpment face, and the outliers. Subsequent inventories of the geology of the park identified the outliers as being provincially significant (Woerns 1977), and identified the McCarston's Lake re-entrant valley, the Orangeville Moraine, and part of the Violet Hill meltwater channel as being significant in the region (Riley 1983; this report).

I would like to thank J. Riley, MNR Aurora, who accompanied the writer in the field and made useful and insightful comments regarding the site, and K. Lindsay, consulting botanist, for insightful comments regarding her detailed life science study of the site. Dr. W.M. Tovell (Royal Ontario Museum, retired) also provided stimulating discussions regarding the glacial geology of the region and the park area. D.K. Armstrong, Ontario Geological Survey, reviewed portions of an early draft of the manuscript.

This inventory of Mono Cliffs Provincial Park is one of a series of geological and ecological inventories of significant natural areas of the Niagara Escarpment, supported by the Ontario Heritage Foundation (Niagara Escarpment Heritage Protection and Land Stewardship Program) and Ontario Ministry of Natural Resources. Logistical support was provided by the Central Region office, Ontario Ministry of Natural Resources, Aurora. The information and recommendations of this report are intended to assist in the appropriate management of the park's resources and the accurate interpretation of the geology of the park.

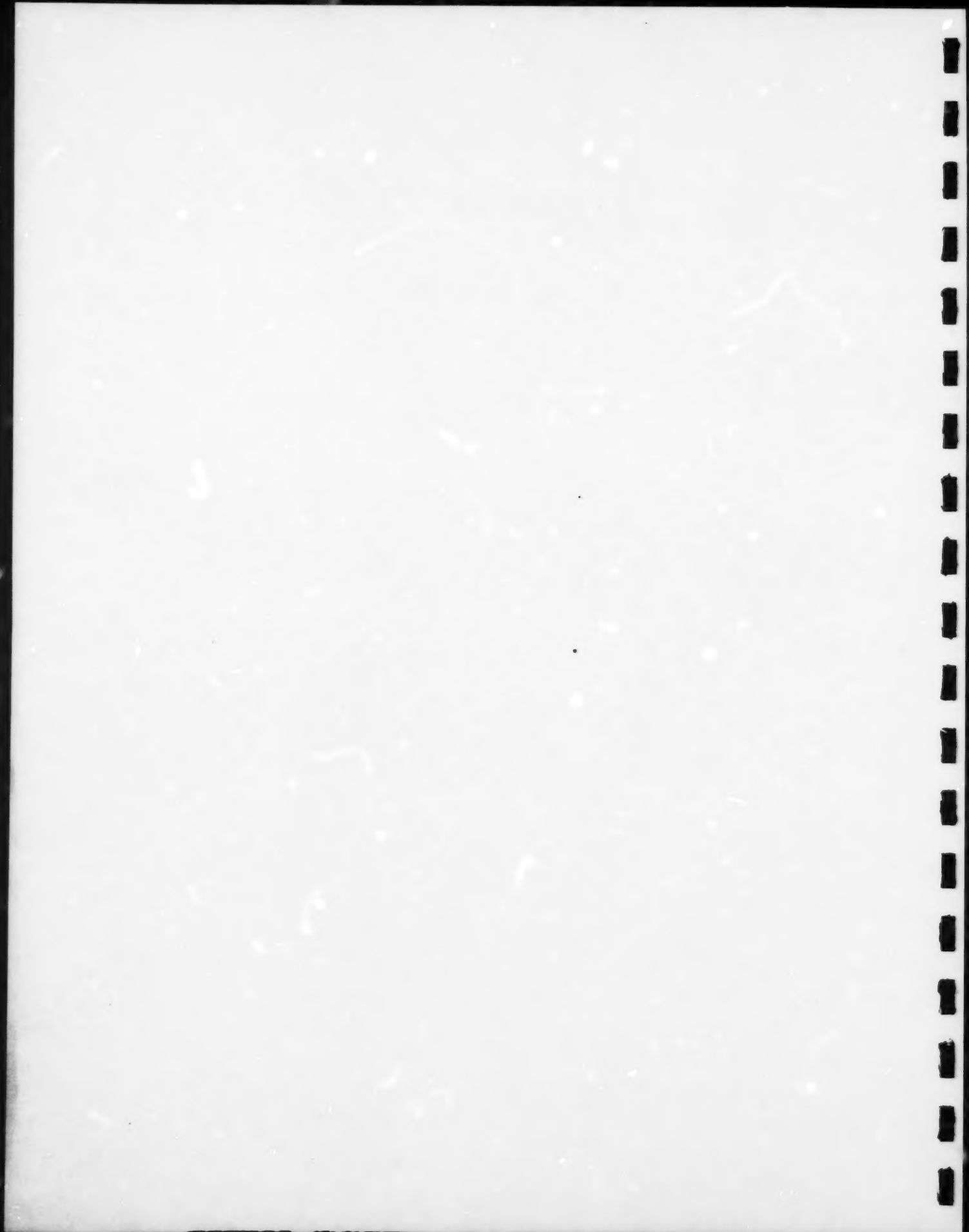


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ABSTRACT

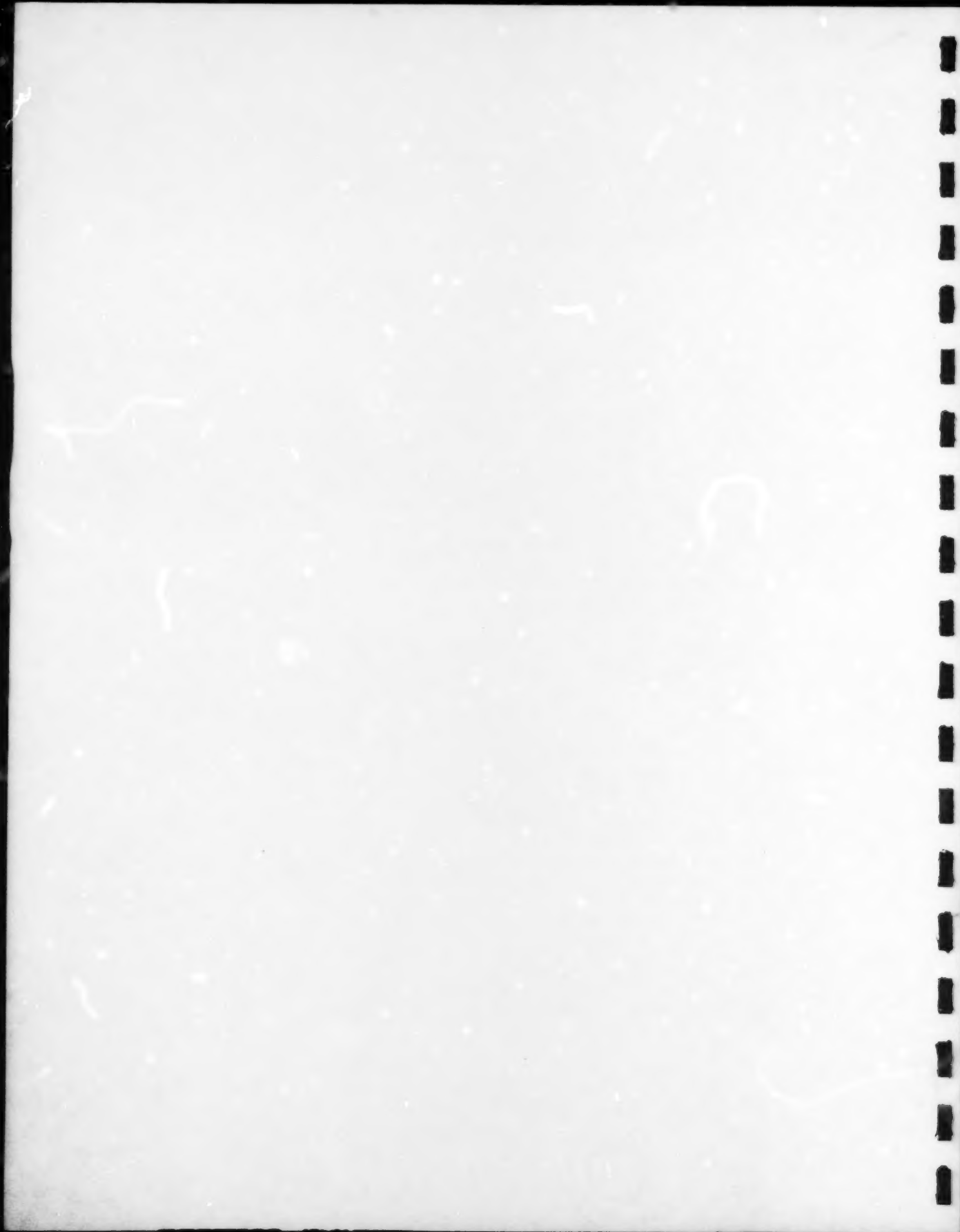
Kor, P.S.G. 1991. An Earth Science Inventory and Evaluation of Mono Cliffs Provincial Park; Ontario Ministry of Natural Resources, Central Region, Aurora; Open File Geological Report 9109, iv + 37 pp, 1 folded map.

Mono Cliffs Provincial Park incorporates an unusually well-exposed portion of the central Niagara Escarpment area. High vertical bluffs of the Silurian Amabel Formation dolostones of the main escarpment face overlook a strong secondary scarp of poorly exposed Manitoulin and Whirlpool Formation sediments, as well as a number of exposures of the underlying Ordovician Queenston Formation shale. The exposed cliffs, almost 30 m high in places, exhibit crevice caves, and their lower portions are mantled by massive talus slopes. Two lozenge-shaped outliers parallel the escarpment edge, the result of differential erosion of surrounding rock. The northern outlier particularly displays deep crevice caves. The two outliers flank a re-entrant valley which locally breaches the escarpment face and is predominantly mantled in glacial drift.

Above the escarpment is the hummocky kame and kettle topography of the Orangeville Moraine. One large water-filled kettle, McCarston's Lake, occurs at the head of the re-entrant valley, surrounded by uncleared forested kame and kettle topography where local groundwater discharge feeds the lake and Sheldon Creek. Preliminary analysis of organic deposits cored from the bottom of the lake indicate that the postglacial climatic history of the region may have been anomalously wet. A minor moraine deposit consisting of large locally derived bedrock material dams this lake and may represent the margin of a stagnant ice block trapped in the re-entrant in the escarpment face, although it has been suggested that this distinctive moraine feature has a more regional distribution and may represent a slight, late readvance of the ice from the east.

Below the escarpment, a gently rolling to flat topography is attributed to two levels of the Violet Hill meltwater channel which drained glacial meltwaters from areas to the north, along and between the Niagara Escarpment and the ice front, which stood at the Singhampton-Gibraltar Moraine complex immediately to the east. The upper (older) meltwater channel level was responsible for removing glacial sediment adjacent to the escarpment and exposing the rock cliffs evident in the park. It also partially excavated glacial sediment between the two outliers and the main escarpment face. The lower (younger) channel level illustrates a slight widening of the channel to the east. The meltwater channel may have indirectly contributed to the formation of extensive crevice systems in the park by clearing and defining cliff edges, thereby undermining them by exposing the softer sediments underlying the Amabel. The postglacial north-to-south drainage reverted to the modern west-to-east, downgrade system of the Nottawasaga River watershed following deflation of the ice lobe occupying the central portions of that basin east of the park.

The park was identified as having provincially significant earth science representation of the outliers associated with the Niagara Escarpment. Also significant are the portion of the Orangeville Moraine and the Violet Hill meltwater channel represented in the park. Of particular significance is McCarston's Lake and its immediate vicinity, notable for an extensive and scientifically interesting organic record. Two levels of the Violet Hill spillway are represented, the result of two periods of use by glacial meltwater flow. Protection of these geological values was identified in the 1974 Park Master Plan, where "Natural Zones" were recommended, and the features are appropriately designated "Escarpment Natural" in the Niagara Escarpment Plan. These protective mechanisms are restated here as recommendations for Nature Reserve Zones, mapped as an area similar in extent to that of the recommended life science Nature Reserve Zones in the park.



CHAPTER 1. REGIONAL CONTEXT

1.1 Introduction

Mono Cliffs Provincial Park is located along the central portion of the Niagara Escarpment in an area where it is mostly drift mantled (Figure 1). At Mono Cliffs however, excellent and almost continuous exposure of the cliffs of the escarpment occur through the park area. The park incorporates massive cliffs of Amabel Formation which divide it into an upper, western area of hummocky kame and kettle topography of the Orangeville Moraine and a lower, eastern area of smooth rolling hills and flat-bottomed valleys formed by the Violet Hill meltwater channel and modern tributaries of the Nottawasaga River.

Two elongate bedrock knolls separated from the main escarpment edge, referred to as outliers, are located east of the escarpment, isolated from it by the meltwater channel. The outliers lie entirely within the boundaries of the park. They were formed during preglacial times by chemical and physical erosion, and subsequently exposed by immediate postglacial fluvial erosion. The outliers were originally considered to be regionally significant (Cowell and Woerns 1976), but were reassessed as provincially significant (Woerns 1977) in consideration of the excellent development and state of preservation of these features. As elsewhere on the escarpment, the outliers are associated with areas of maximum glaciofluvial activity, in this case the re-entrant valley and the meltwater channel.

In conjunction with a number of other nearby sites, notably Violet Hill Channel-Boyne Valley ANSI and Pine River ANSI to the north, Mono Cliffs Provincial Park includes features representing the diverse geological themes of the central portions of Niagara Escarpment.

Mono Cliffs Provincial Park is located about 8 km north of Orangeville, in Mono Township, Dufferin County, at 44°03'N Latitude and 80°04'W Longitude (NTS 41 A/1, centred on UTM 745775). The community of Mono Centre is located at the southwestern edge of the park. Access is via Dufferin County Road 8 from Highway 24-10, and from numerous minor roads east of the highway. The site is bounded by 1st Line E.H.S. and 2nd Line E.H.S. (west), 25 Sideroad (north), and 3rd Line E.H.S. (east). The Bruce Trail passes through the middle of the park in a north-south to westerly direction. Auto access to the trail system is by parking lots in the western portions of the park and at Mono Centre. At this writing, no facilities have been constructed in the park. The park covers an area of about 730 ha.

This inventory of Mono Cliffs Provincial Park involved 3 days of pre-field preparations, 10.5 days of field work and 22 days of report writeup. The pre-field preparations consisted of data accumulation, including all pertinent maps, airphotos (1:10,000 scale), geological reports, and discussions with staff from the Ontario Geological Survey. Three reports dealing specifically with the geology and geomorphology of the park (Patten 1973; Warren 1973; Riley 1983) proved helpful in defining the regional context of the features and in identifying significant areas within the park.

Field work, completed during the summer of 1990, consisted of driving all roads through the area, walking the Bruce Trail and its side loops, and traversing portions of the area using pace-and-compass techniques. The bedrock sections of the escarpment were measured and sampled at accessible locations in the cliffs of the Niagara Escarpment. Rock outcrops were studied for rock type, contacts, sedimentary structures, and surface features.

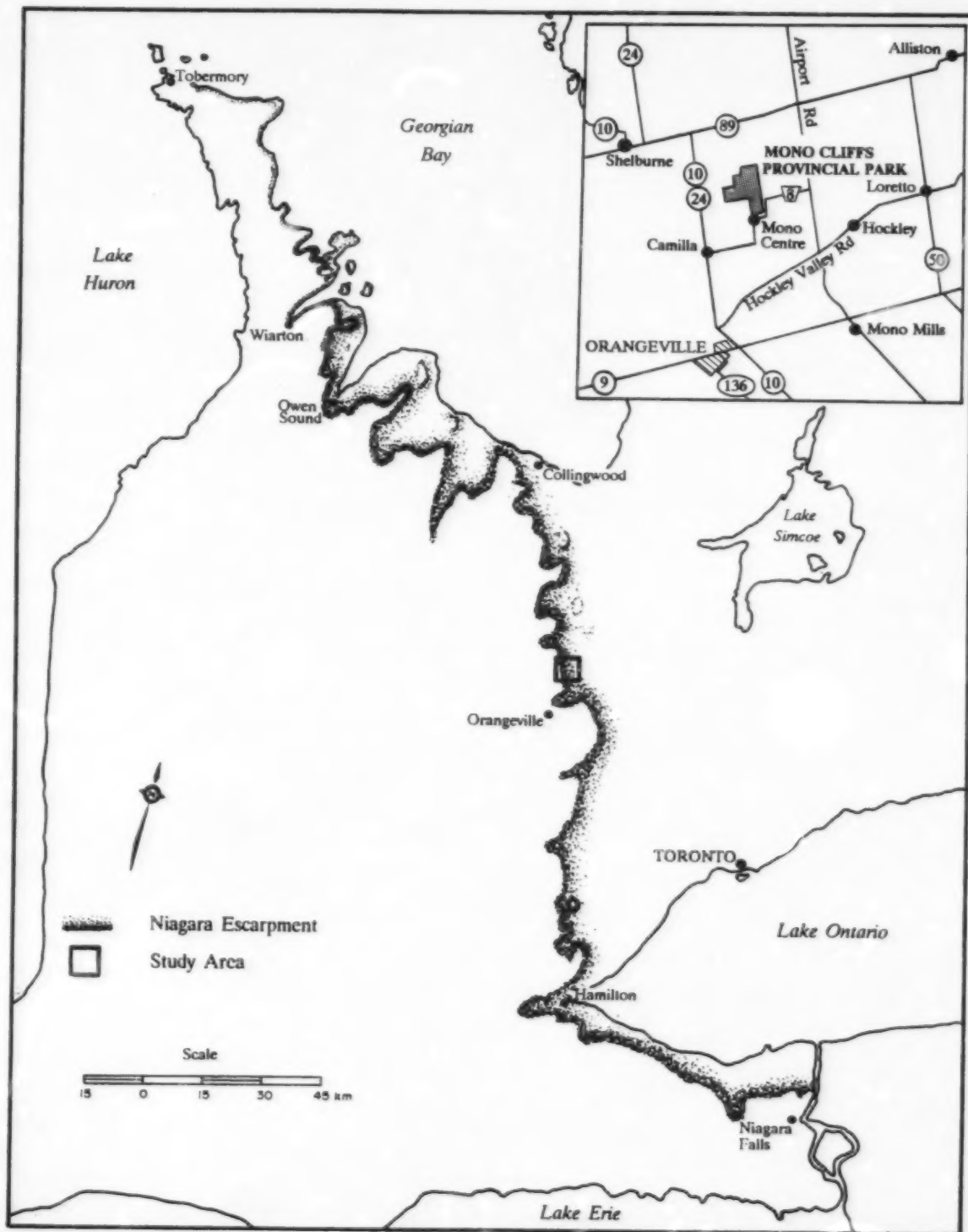


Figure 1. Location map, Niagara Escarpment and Mono Cliffs area.

Vertical exposures in the glacial drift of the area are not common. Where roads cross major topographic breaks, such as in the banks of the Violet Hill meltwater channel, good exposures of the glacial sediments are present. A few local gravel pits, abandoned and active, also provided good vertical exposures outside the park area. Study of the surficial component of most of the park was generally restricted to airphoto interpretation, published literature review, and hand-augered holes and cores.

1.2 Bedrock Geology

The bedrock underlying the study area are clastic and carbonate sediments of Paleozoic age. These rest unconformably on the Precambrian basement complex of the Canadian Shield at a depth of over 1350 m (Bezys and Johnson 1988). In southwestern Ontario, the Paleozoic sequence consists of Cambrian through Mississippian strata outcropping in concentric belts around the southwest trending Precambrian rise called the Algonquin Arch (Figure 2). The present study region consists of southern Ontario's most prominent topographic feature, the 600 km long Niagara Escarpment (Figure 2).

Bedrock exposures along the escarpment represent only a thin slice of the Paleozoic sequence, from the lower Queenston Formation and, rarely, the Georgian Bay Formation (Upper Ordovician), upsection through the Cataract (Lower Silurian), Clinton and Albemarle Groups (Middle Silurian). This succession was largely deposited in fluctuating, shallow marine environments between two deeper basins, the Michigan to the north and the Appalachian to the south about 450 to 415 million years ago. Sedimentation in these deeper basins was much greater than over the Algonquin Arch, which was periodically exposed above sea level. The result is that thick sediment packages are preserved in the basin areas, whereas equivalent units over the arch are thin or lacking. The relatively thin composite section exposed in the park is a reflection of sedimentary conditions over the arch.

The regional stratigraphic sequence is complicated by lateral facies changes as a result of different depositional environments reflecting differences in the distance from the material source and the depths of water in fluctuating seas. As a result, the predominantly clastic sediments typical of the Appalachian basin interfinger with mainly carbonates typical of the Michigan basin in complex onlap-offlap patterns over the Algonquin Arch (Sanford 1969; Telford and Johnson 1984).

The clastic rocks of the Appalachian basin, predominantly sandstones and shales, were created by the erosion of adjacent highlands, the Taconic Mountains (ancestral to the Appalachian Mountains) to the southeast and to a lesser degree the Canadian Shield to the north (Bezys and Johnson 1988). The significant thickening of this sedimentary package to the southeast reflects the strong influence of the Taconic Mountains and the decreasing distance from the original sources of material. In the shallow Michigan basin, carbonate sedimentation predominated, because sources for clastic sediments were minimal.

In southwestern Ontario, sedimentation during the Silurian was greatly influenced by an actively rising (or subsiding at a slower rate than adjacent basins) 'spine' in the Precambrian basement complex called the Algonquin Arch, which served to complicate the relationships between the sediments in the adjoining basins. The Paleozoic sedimentary strata were originally deposited as flat-lying units. Subsequent tectonic activities resulted in gentle, regional dips, generally to the southwest.

In Ontario, the Niagara Escarpment consists of a prominent, exposed bedrock ridge from the Niagara River west to Dundas and northward to about Milton, northwestward from Collingwood through Owen Sound, and along the Bruce Peninsula and Manitoulin Island to St. Joseph Island. The central portion between Milton and Collingwood is mostly buried or thinly veiled by glacial debris. Anomalous to this veiled central portion of the escarpment are the excellent bedrock exposures in the Mono Cliffs area.

Compiled by B.A. Liberty and D.F. Hewitt 1972 and
P.G. Telford 1976, 1987. Simplified for this report.

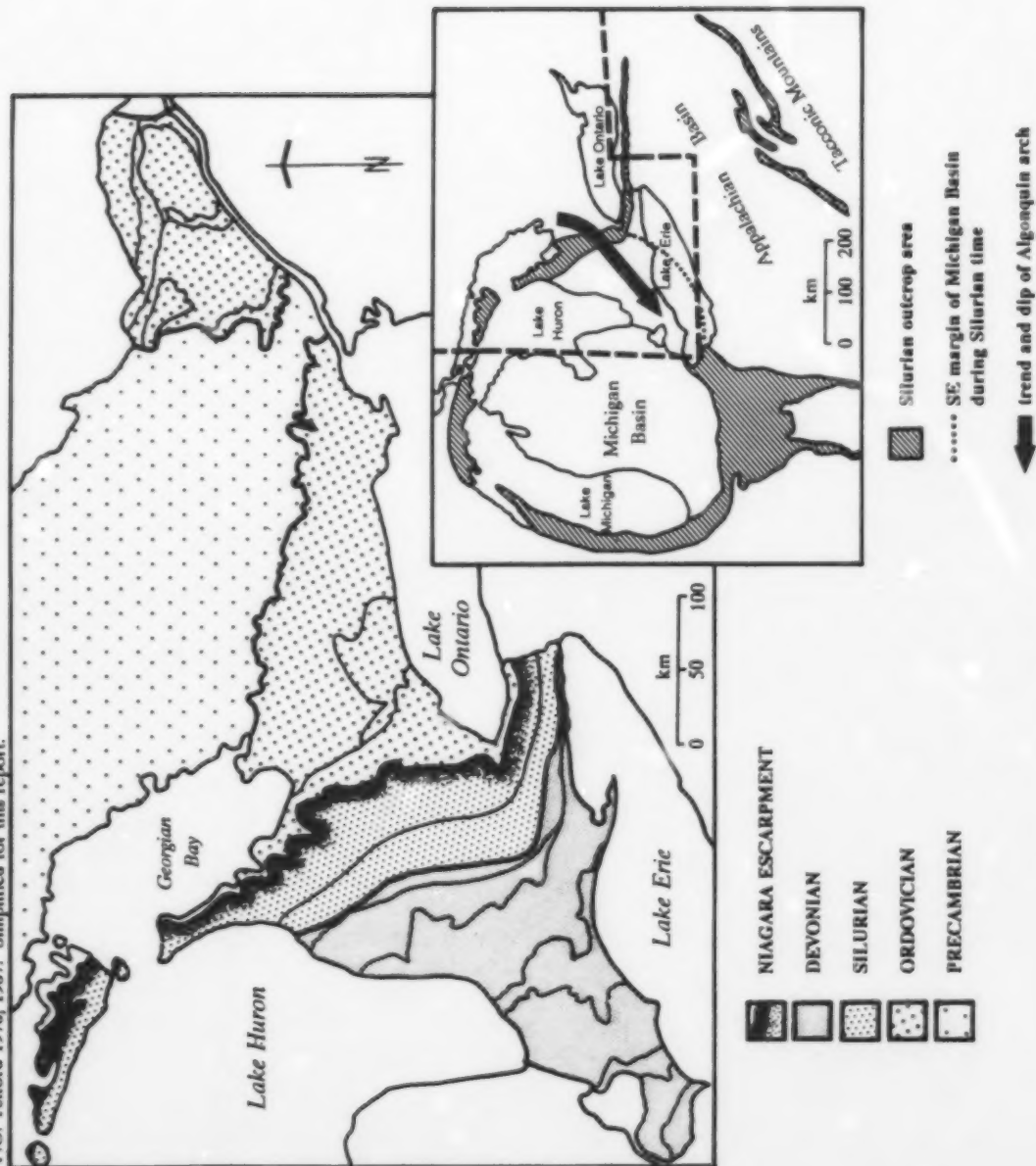


Figure 2. Structural elements of southwestern Ontario and location of the Niagara Escarpment.

The escarpment is an erosional feature, created by the removal of relatively soft shales from beneath a more resistant caprock of massive carbonates. The portion of the escarpment over the Algonquin Arch, a relatively higher element of the depositional basin, is deeply cut, resulting in its greatest relief of about 287 m, near Collingwood (Hewitt 1971). Elsewhere, however, the escarpment is represented by a local topographic rise where it is masked by glacial debris. Glacial and postglacial fluvial clearing and modification of promontories, outliers and other irregularities along the escarpment enhanced and defined their size and shape, and cut through and removed debris from re-entrant and outlier valleys (Karrow 1987; Straw 1968).

The Ordovician and Silurian sediments exposed in the Orangeville area portion of the escarpment were deposited squarely over the Algonquin Arch, and were influenced by conditions in both the Appalachian and Michigan basins. Most units in the Appalachian basin thin from east to west, from Queenston to about Georgetown (Figure 3). Over the arch, they interfinger with the more uniform carbonate facies rocks deposited in the tectonically more stable Michigan basin. The upper portion of the sequence tends to be of a clastic carbonate nature due to the shallowness of the seas across the arch.

The shales of the Queenston Formation were deposited in an expanding delta complex over vast portions of the Late Ordovician sea, resulting in the fairly consistent occurrence of the unit throughout its exposure along the Niagara Escarpment. The onset of the Silurian saw a greater influence of structural and environmental controls on the basin topography, resulting in regionally less uniform sedimentary patterns.

The Early Silurian saw near-continuous deposition of the Cataract Group sedimentary package, reflecting a transgressive-regressive cycle of sedimentation in which normal marine sandstones gave way to deltaic redbeds and carbonates. Sedimentation over the Algonquin Arch consisted of carbonate deposits due to the shallower conditions. The close of Cataract time saw the continued but waning effects of the Taconic upland area.

During Clinton time, the seas which covered the region periodically retreated, creating interfingering packages of clastic and carbonate sediments. Interfingering thin strata of sandstones and siltstones, reflecting smaller input from adjacent upland areas, with thick carbonate strata in the eastern portions of the Appalachian basin reflect this continued but waning influence of the Taconic Mountains.

A relative shallowing of the Clinton seas provided widespread environments suitable for crinoid bank development, that is, shallow subtidal flats (Sanford 1969; Winder and Sanford 1972). The high energy crinoid bank areas at the edge of a rapidly subsiding Michigan basin separated deepwater sedimentation to the north from a shelf lagoon environment to the south, resulting in complex lateral facies relationships during Albemarle time. Subsequent widespread dolomitization further obscured the relationships between these rocks.

The rocks of the Niagara Escarpment are identified by their lithostratigraphy (physical sedimentary characteristics) and partly by their biostratigraphy (distribution of flora and fauna), which is best established on the Niagara Peninsula. These aspects of the geology of the escarpment are well documented in the classic works of Bolton (1957), Liberty (1969), Sanford (1969) and Liberty and Bolton (1971). Although their classification scheme is not unanimously supported by others in the field, the breakdown of the stratigraphy into the formations and members described herein (Figure 4) follow accepted nomenclature adopted by the Ontario Geological Survey based on the classic references cited above, and the mapping by Liberty et al. (1976).

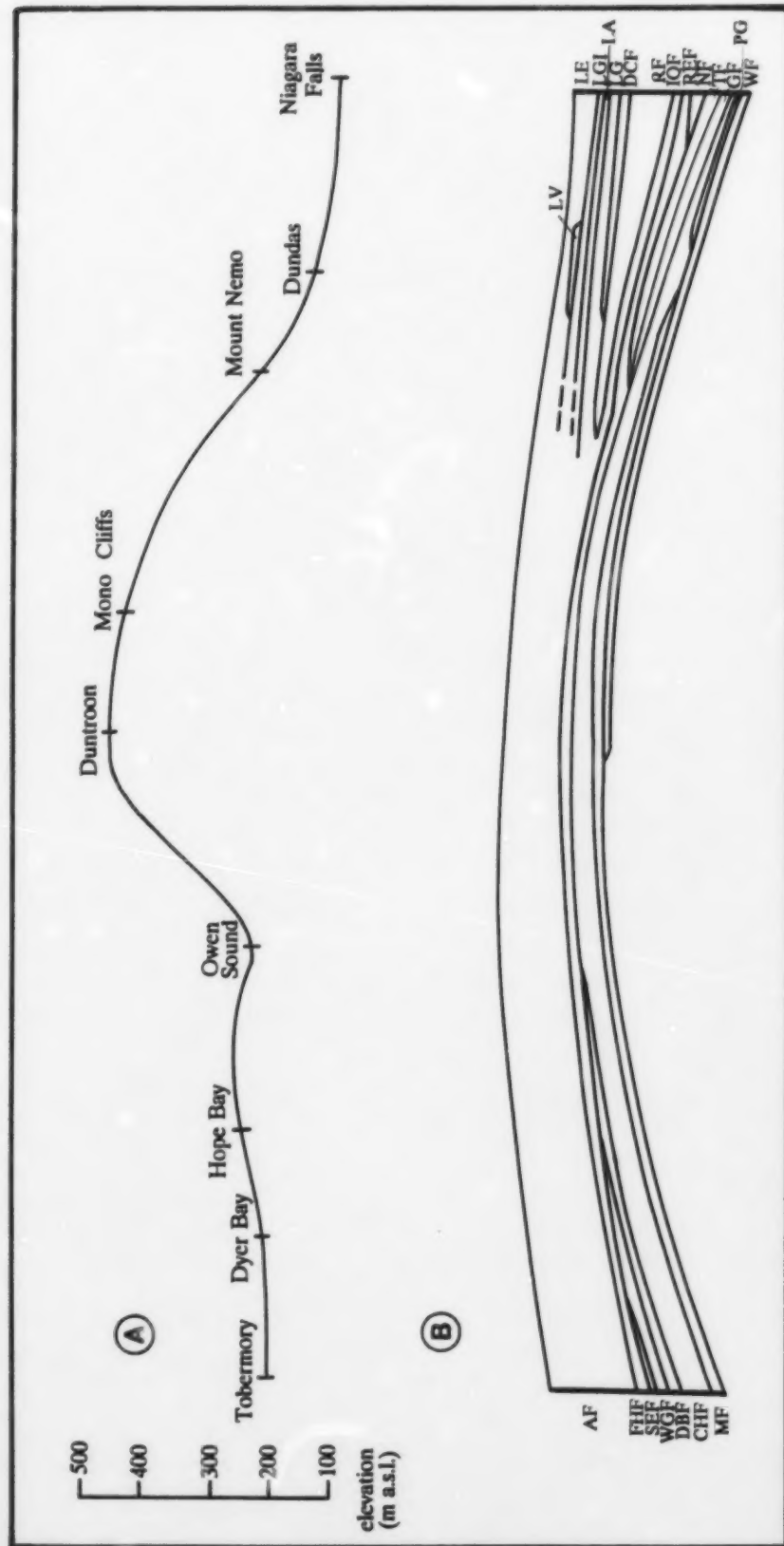


Figure 3.

Stratigraphy of the Niagara Escarpment: a cross section from Tobermory to Niagara Falls;

A) Simplified elevation of the brow of the escarpment; B) Idealized schematic cross section showing relationships of units (not to scale). Unit abbreviations are as follows: AF-Amabel Formation; FHF-Fossil Hill Fm; SEF-St. Edmund Fm.; WGF-Wingfield Fm; DBF-Dyer Bay Fm; CHF-Cabot Head Fm; MF-Manitoulin Fm; LE-Lockport Fm (Eramosa member); LV-Lockport Fm (Vincemount shale beds); LGL-Lockport Fm (Goat Island member); LA-Lockport Fm (Gasport member); DCF-DeCew Fm; RF-Rochester Fm; IQF-Irondequoit Fm; REF-Reynolds Fm; NF-Neahga Fm; TF-Thorold Fm; GF-Grimsby Fm; PG-Power Glen Fm; WF-Whirlpool Fm. The Guelph Fm forms the top unit at or near the brow of the escarpment from Tobermory to Niagara Falls.

		Bruce Peninsula	Algonquin Arch	Niagara Peninsula
	ALBEMARLE GROUP	GUELPH Eramosa	GUELPH Eramosa	GUELPH
		AMABEL Warton/ Colpoy Bay Lions' Head	AMABEL unsubdivided	LOCKPORT Eramosa Vincemount Goat Island Gasport
MIDDLE SILURIAN	CLINTON GROUP	FOSSIL HILL ST. EDMUND WINGFIELD DYER BAY	FOSSIL HILL	DECEW ROCHESTER IRONDEQUOIT REYNALES NEAHGA THOROLD
LOWER SILURIAN	CATARACT GROUP	CABOT HEAD MANITOULIN	CABOT HEAD MANITOULIN WHIRLPOOL	GRIMSBY CABOT HEAD MANITOULIN WHIRLPOOL
UPPER ORDOVICIAN		QUEENSTON GEORGIAN BAY	QUEENSTON GEORGIAN BAY	QUEENSTON GEORGIAN BAY

Figure 4. Table of Formations, Niagara Escarpment (after Bolton 1957 and Winder and Sanford 1972).

1.3 Surficial Geology

The Precambrian Algonquin Arch forms the topographic spine of southwestern Ontario, and created an upland peninsula projecting between four lake basins (Figure 2): Huron and Georgian Bay to the north, Erie to the southwest and Ontario to the southeast. Because of this topographic control, the margins of the Wisconsin Laurentide ice sheets, originating from the northeast, were strongly lobate, with each lake basin being occupied by a major projection of the ice front.

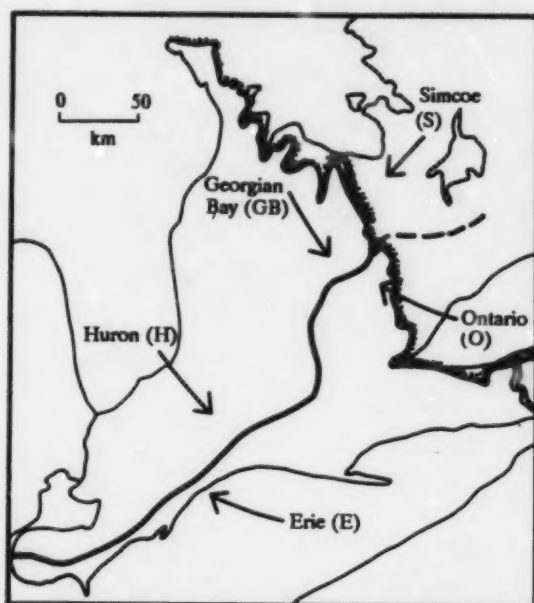
During periods of glaciation, southwestern Ontario was invaded by ice lobes expanding outward from each of these basins, creating a suture zone where they coalesced. During periods of ice retreat, a series of roughly concentric end moraines formed on the central upland, subaerially exposing an area surrounded by ice on three sides and glacial lakes to the southwest. Taylor (1913) called this emerging upland the "Ontario Island". With continued ice retreat, parts of the peninsula were flooded by waters of a succession of glacial lakes dammed between the ice and the drainage divide south of the Great Lakes. It is likely that this sequence of events was re-enacted during each successive glacial episode of the Wisconsin.

The central escarpment region encompasses features of glacial erosion and deposition which illustrate a complex sequence of events, the consequence of the last glacial events to mark the Late Wisconsin in the area (Figure 5). Glacial lobes advancing from the Georgian Bay basin to the northeast (with a sublobe from the Simcoe basin) and from the Ontario basin to the southeast invaded the escarpment along this section, while the Huron lobe to the west served to contribute sediment and to control the movement and meltwater flow of the other lobes. During deglaciation, interlobate areas became centres of deposition and erosion due to concentrated meltwater flow. The emerging Niagara Escarpment influenced these late glacial events as ice became thin and more susceptible to the control by the influence of its topography and morphology.

The Niagara Escarpment is marked by a number of indentations or re-entrants, the origin of which are the subject of some controversy. Chapman and Putnam (1984) and Karrow (1963;1987) believe that these re-entrants in the escarpment represent preglacial drainage valleys which were enhanced by glacial erosion. Straw (1968), on the other hand, contends that the straight, overdeepened shape and consistent orientation of most of the re-entrants in the escarpment suggest an origin almost wholly related to glacial erosion. Shaw and Gilbert (1990), Barnett (1990) and others suggest that during the Late Wisconsin, subglacial meltwater floods, released catastrophically, were responsible for extensive landform modification throughout much of southern Ontario. The extreme erosive power of these types of flows on a variety of substrates, including bedrock, is demonstrated elsewhere (Shaw and Kivill 1984; Kor et al. 1991). The Orangeville and Hornings Mills re-entrants, and probably lesser re-entrants along the Niagara Escarpment between these two, such as at Mono Centre, may be in part a product of this process.

During the Late Wisconsin, much of the Niagara Escarpment remained essentially ice-covered while high ground coincident with the Algonquin Arch was repeatedly cleared of glacial ice. The central portions of the Niagara Escarpment were affected by a number of advances and retreats during this time. The topographic break of the escarpment served to channel ice and particularly meltwaters during several Late Wisconsin stadials and interstadials (Straw 1968; Chapman and Putnam 1984).

The last strong ice advance to affect the region occurred during the Port Bruce Stadial, culminating about 14 000 BP (years Before Present), essentially covering southern Ontario completely (Dreimanis and Karrow 1972). Its deterioration was initiated along a complex interlobate seam between the northern and southern ice lobes. In the region of the park, this interlobate zone is marked by the Orangeville Moraine, a massive deposit of hummocky ice-contact and glaciofluvial sediment formed between the Georgian Bay lobe from the northwest and the Simcoe sublobe from the northeast (Figure 6a). The moraine trends south-southwest above the brow of the Niagara Escarpment from Hornings Mills to an area 30 km southwest of Orangeville (Gwyn 1975). The southern position of the moraine represents the contact zone of the Georgian Bay and Ontario lobes.



a. Port Bruce maximum 14000 BP



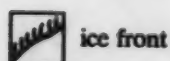
b. Late Port Bruce Stadial 13300 BP



c. Port Huron maximum 13000 BP



d. Lake Iroquois (Ontario basin) 12000 BP



ice front



ice movement



lake

Figure 5. Regional glacial history - southwestern Ontario and central Niagara Escarpment area. (adapted after Chapman and Putman 1984).

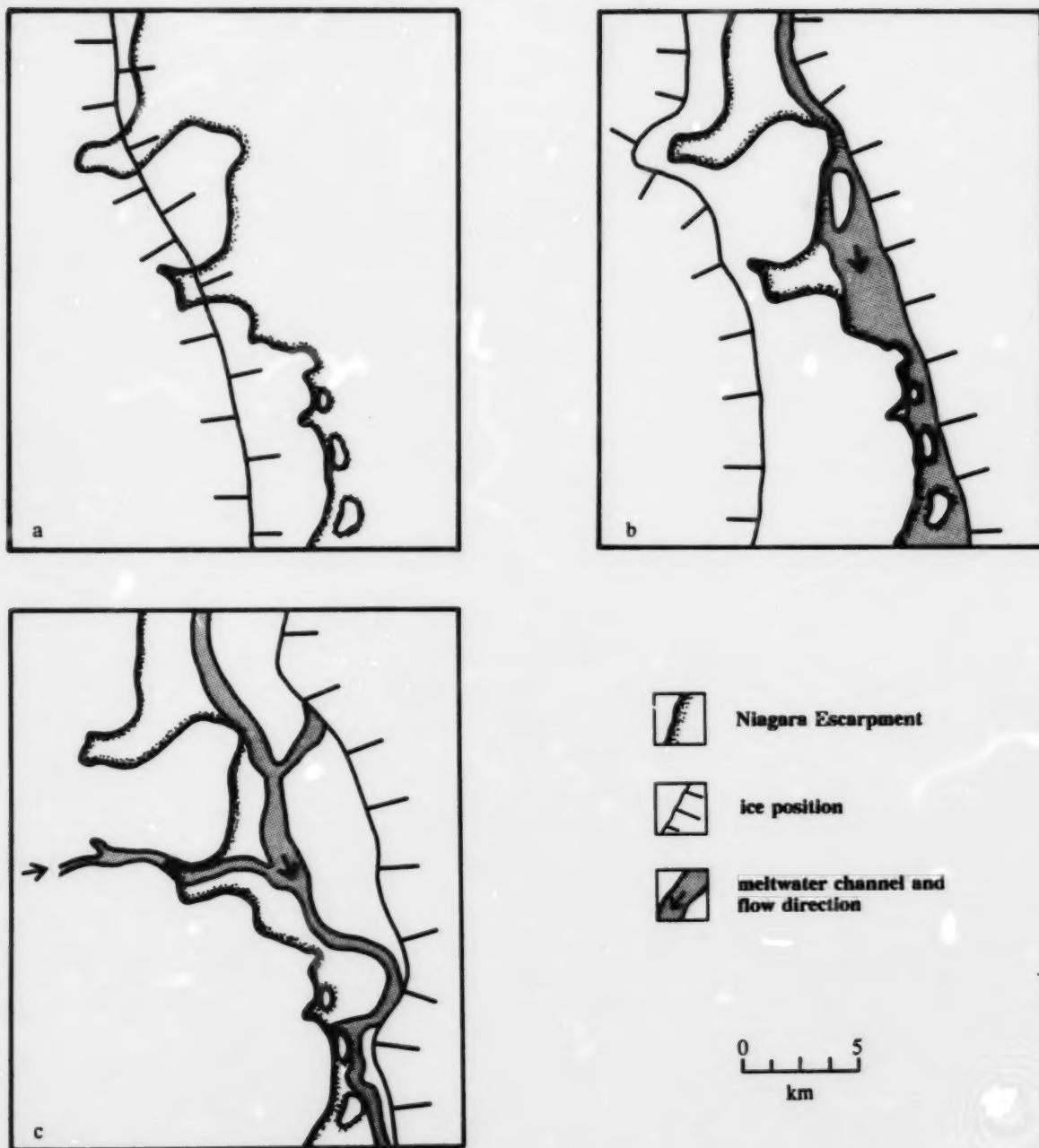


Figure 6. Main events during the deglaciation of the Violet Hill-Mono Cliffs area of the Niagara Escarpment.

- a Deglaciation begins along a suture zone between the Huron lobe (west) and Georgian Bay lobe (east), initiating the Orangeville Moraine.
- b Retreat to the western Orangeville Moraine position above the escarpment and the Singhampton Moraine position below the escarpment; the initial, high level of the Violet Hill meltwater channel flows adjacent to the Singhampton Moraine.
- c Retreat of Huron lobe ice out of the region allows breaching of the Orangeville Moraine, and slow stagnation of the Georgian Bay lobe to the Gibraltar Moraine position produces a lower channel of the Violet Hill meltwater channel through the area.

During further retreat of adjacent ice lobes, the Simcoe sublobe (Georgian Bay lobe) remained vigorous and persisted in the Hockley Valley to the south (Cowan 1976). The Georgian Bay lobe and the Simcoe sublobe retreated from the Orangeville Moraine to the Singhampton Moraine, a broad ice-stagnation complex above the Niagara Escarpment to the north, and below the escarpment towards the south. In the Mono Cliffs area, this ice position is marked by the Singhampton Moraine below the escarpment (Figure 6b).

Further retreat, or possibly retreat with a readvance, was halted at the Gibraltar Moraine position, which forms a distinct feature north and south of the Mono-Mulmur Township area, but which is not morphologically distinguishable from the Singhampton Moraine in the study area (Figure 6c). Here the ice may have been delayed in its retreat due to a locally higher elevation and cooler temperatures, resulting in a wide area of mass stagnation, or a subtle two-stage retreat (Riley 1983). The coalescence of the two ice positions through this area is also recognized by Chapman and Dell (1963).

During retreat of Port Bruce ice from the area, complex meltwater channel systems evolved which drained meltwaters from the ice front to glacial lakes south of the emerging "Ontario Island". Meltwaters from the ablating glaciers were channelled between the Orangeville Moraine and the Niagara Escarpment to the west and, first the Singhampton Moraine (Figure 6b), then the Gibraltar Moraine to the east (Figure 6c). The confined flow created flat-bottomed channels between these restrictions, exposing bedrock along the Niagara Escarpment in places, and cutting through moraine deposits elsewhere. In the park the Violet Hill meltwater channel (Lavender-Violet Hill Meltwater Channel of Gwyn 1975) marks the course of this meltwater. It flowed south from here, possibly into a water body ponded by an ice dam in the Hockley valley (Riley 1983) (Figure 7). At least two levels of the Violet Hill meltwater channel are recognizable in the park. The main elements and course of the Violet Hill meltwater channel are summarized in Figure 7.

Glacial readvance during the Port Huron Stadial, about 13 000 BP, in the central Niagara Escarpment area surmounted the escarpment to the Banks Moraine (Georgian Bay lobe) north of the study area, and re-entered the Hockley valley (Simcoe sublobe) south of the study area. Retreat of these glaciers subjected the Niagara Escarpment to further subaerial erosion by runoff.

Following the decay of the ice lobe to the east, the Violet Hill meltwater channel was no longer confined to flow southward through the Orangeville and Hockley Valley area. Meltwaters were redirected eastward by the regional slope, accumulating in the postglacial Schomberg ponds below the Singhampton and Gibraltar Moraines. This eastward shift of drainage is reflected in the modern stream channels to the east of the park, where Sheldon Creek flows through modern valleys across the Singhampton-Gibraltar Moraine, east to the Nottawasaga River.

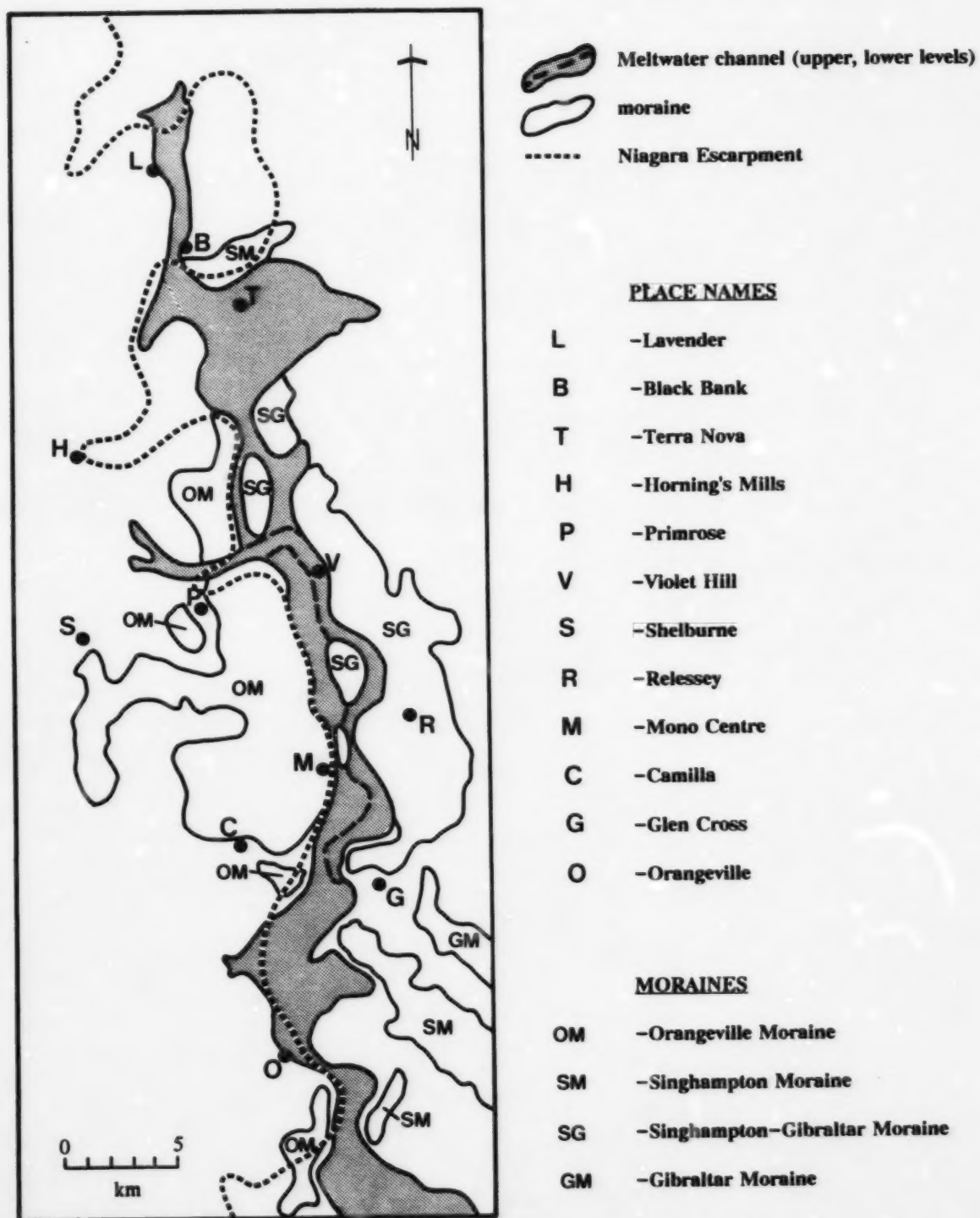


Figure 7. Simplified schematic showing location of main elements of the Violet Hill meltwater channel.

CHAPTER 2. GEOLOGY AND GEOMORPHOLOGY OF MONO CLIFFS PROVINCIAL PARK

2.1 General Character

Mono Cliffs Provincial Park encompasses a glacial landscape primarily related to deglaciation of Port Bruce Stadial ice from the area. Generally, the site can be divided into four broad physiographic zones: knob and kettle topography of the Orangeville Moraine; a narrow linear zone of strong bedrock cliffs of the exposed Niagara Escarpment, including a small re-entrant valley; two cliff-bounded outliers of the escarpment; and the low rolling topography of the Violet Hill meltwater channel. Minor portions of the subdued topography of the Singhampton-Gibraltar Moraine complex also occur in the park.

The western portion of the site, above the steep cliffs of the Niagara Escarpment, consists of a rolling, hummocky landscape composed of ice-contact sands and gravels of the Orangeville Moraine. This area is characterized by a low relief knob and kettle topography, of which the largest water-filled kettle, McCarston's Lake, is the dominant feature.

The eastern portion of the park, below the escarpment, is dominated by the Violet Hill meltwater channel, which carried meltwaters southward between banks consisting of ice on the east and the Niagara Escarpment on the west. The meltwater channel consists of a broad, sinuous, flat-bottomed valley with several terraces marking different water levels representing successive use through time. Two main channel levels indicate that meltwaters first flowing through the area from the north were confined by ice at the Singhampton Moraine position, causing it to excavate the Niagara Escarpment and its Whirlpool-Manitoulin secondary scarp in places. Two elongate outliers of the escarpment were also accentuated by the removal of much of the intervening sediment by this meltwater flow. A second period of flow cut a channel closer to the Gibraltar Moraine position to the east, through the higher channel level into the bedrock of the Queenston Formation. The channels are for the most part cleared of forest and their character is very evident from the surrounding uplands.

Bedrock crops out predominantly along the high cliffs through the middle of the park, and at the edge of a lower secondary scarp, exposing an incomplete section typical to the central portion of the escarpment, from the Upper Ordovician Queenston Formation upsection to the Middle Silurian Amabel Formation. The strong cliffs and secondary scarp are unusual here because the central portion of the escarpment is more commonly masked by thick glacial sediments. The preservation and exposure of two steep-walled outliers adjacent to the escarpment is also significant.

2.2 Site Description

In this section of the report, the bedrock formations exposed in the park will be described and compared to their regional occurrence. The location of representative sections will also be presented. Reference should be made to the Table of Formations (Figure 4) while reading this section. A discussion of the Quaternary sediments and landforms in the study area is also presented. All reference sites are located on Figure 8; UTM grid coordinates are based on Ontario Base Maps 5700 48750 and 5750 48750 (scale 1:10,000). The geology of Mono Cliffs Provincial Park is described in chronological order from oldest to youngest, and is presented on Map 1 (back pocket).

a) *Bedrock Geology*

Bedrock outcrop within the park occurs along the cliffs of the Niagara Escarpment and sporadically along the edge of a secondary scarp below the main escarpment face. Although the Manitoulin, Fossil Hill, and

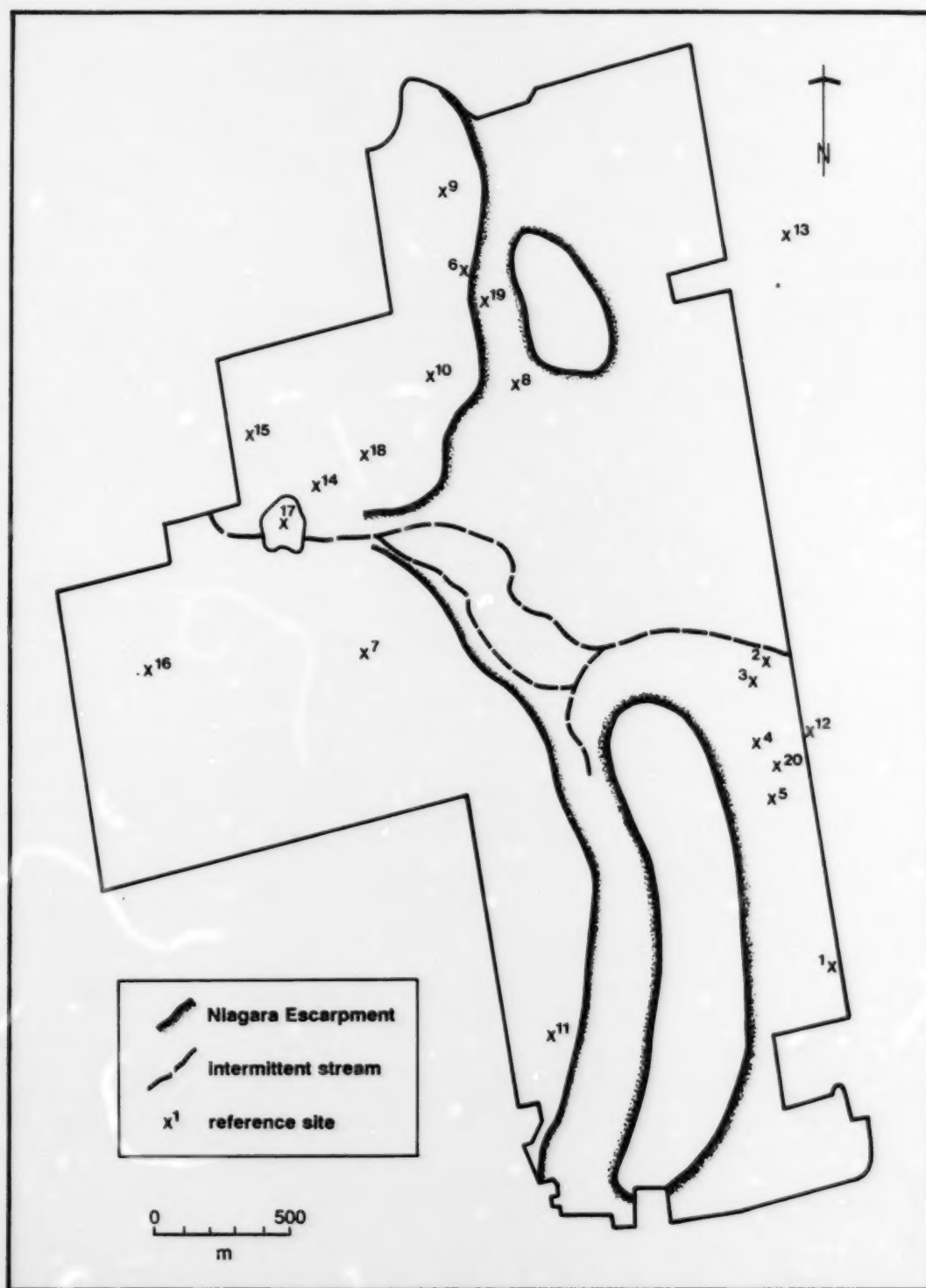


Figure 8. Location map of reference sites in Mono Cliffs Provincial Park (for more detailed location, see UTM grid coordinates in text).

Cabot Head Formations are recognized to occur between the Whirlpool and Amabel Formation in the area (Liberty et al. 1976), these were not observed in the study area and are thus not described here.

Queenston Formation (Upper Ordovician) The Queenston Formation (also referred to as the Queenston shale) is predominantly a red shale, commonly exposed at the base of the Niagara Escarpment. Its eroded, weathered upper surface, dissected by eastward-draining streams, creates the hummocky topography of much of the terrain east of the escarpment. The lithology of the unit, consistent throughout its occurrence, is a dark red, hematitic, blocky, non-fissile calcareous and clay shale characterized by thin interbeds of grey, sublithographic, argillaceous limestone (Liberty et al. 1976). Grey-green reduction zones subparallel or transverse to the bedding are common. The unit may be over 100 m thick in the region.

Red to brown-red, clay-rich shale of the Queenston Formation is exposed in a road cut at the southeastern edge of the park (Figure 9: Site 1, UTM 754763). Over 6.5 m of the unit is exposed in a fresh section below a cap of Whirlpool Formation sandstone at the edge of the secondary scarp below the main escarpment. Distinct grey-green reduction zones occur throughout the exposure, dominated by a 2 m thick zone below the Whirlpool contact. This contact zone is also marked by sulphide staining from pyritiferous inclusions in the overlying Whirlpool sandstone. The shale is very clayey in weathered surfaces, and contains very few competent limestone interbeds. The only other occurrence of Queenston shale in the park was noted north of this site, in the trampled surface of a livestock enclosure (Site 2, UTM 751773). The unit likely underlies the lower level of the Violet Hill meltwater channel in the park, and the Singhampton-Gibraltar Moraine complex to the east of the park (Liberty et al. 1976).

Whirlpool Formation (Cataract Group: Lower Silurian) The Whirlpool Formation is typically a very fine-grained, well sorted, light grey, calcareous cemented quartz sandstone (Liberty et al. 1976). Bedding is generally thin, with planar and cross bedding commonly exposed in vertical section. Thin, green, shale partings, inclusions and mud-galls are common, particularly near the top of the unit (Bolton 1964; Liberty et al. 1976). Contacts are distinct, and the unit has a variable thickness between 4 m and 9 m, thinning considerably northward to about 2 m at Collingwood.

The Whirlpool is best exposed at the road cut noted above, where it overlies the red shale of the Queenston Formation (Figure 9; Site 1). Here it is a thin-bedded to massive, coarse-grained, granular sandstone, pale yellow-buff to buff-grey in colour. The unit is about 3 m thick at this site. Liberty et al. (1976) note this exposure to be one of the best in the immediate region. In the only other exposure in the park, north of this site (Figure 10; Site 3, UTM 751772), cross bedding is evident in weathered surfaces. These exposures occur at the edge of a broad flat bedrock plain overlain by glaciofluvial sediment (typical site example at Site 4, UTM 750770). This bedrock plain represents a secondary scarp formed by the relatively thin but resistant Whirlpool and Manitoulin Formations below the main Amabel bluff of the Niagara Escarpment in the region. Abundant Whirlpool rubble litters the slope of the scarp between the two exposed bedrock sections in this area (example at Site 5, UTM 751768), attesting to its proximity to surface here. Some Manitoulin rubble was also noted in this scarp face, but bedrock exposure of the Manitoulin Formation was not found in this survey.

Amabel Formation (Albemarle Group: Middle Silurian) The Amabel Formation is a reefy dolostone which forms the caprock of the northern portions of the Niagara Escarpment. Its southernmost extent is recognized in the abandoned Kerns Road Quarry near Waterdown (Telford and Johnson 1984). Northward on the Ontario mainland, the Amabel is recognized to the northern tip of the Bruce Peninsula. Two members can be distinguished north of about Georgetown: the lower Lion's Head and upper Wiarton/Colpoy Bay members (Liberty and Bolton 1971). The Eramosa is classified as part of the Guelph Formation (Sanford 1969; Armstrong and Goodman 1990). Between Georgetown and Waterdown, the Amabel grades laterally into the Lockport Formation, with which it is correlative, resulting in a mixing of lithologies which makes differentiation into members very difficult (Bolton 1957). The present study area is

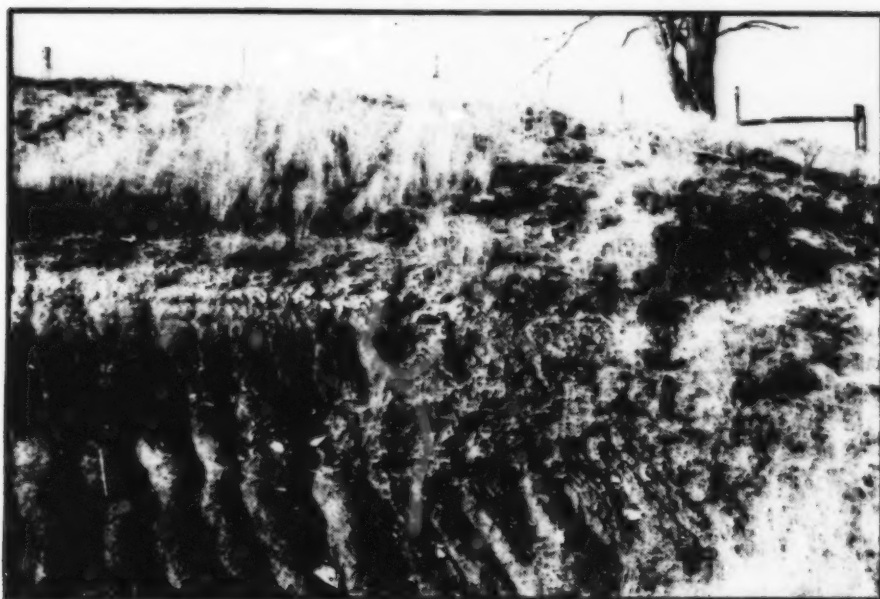


Figure 9. Roadcut showing Queenston Formation shale overlain by Whirlpool Formation sandstone (Site 1). The light-coloured horizontal bands in the dark red shale are green reduction horizons. Adze (lower left) for scale is 90 cm long.



Figure 10. Surface exposures of Whirlpool Formation sandstone above the brow of the secondary scarp (Site 3). Rock hammer (lower central portion; 29 cm long) for scale.

situated north of this transition zone. However, although textural and lithological variations allow recognition of the various members through this region, this is difficult in the study area because of the uniformity of the unit here (Bolton 1957; Liberty et al. 1976). Liberty et al. (1976) suggests that the Colpoy Bay and Warton members are likely the dominant subdivisions in the region, with the possibility of the occurrence of a thin basal Lion's Head member at Hornings Mills. Regionally, the Amabel is described as a massive, unbedded, white to grey, fine-crystalline dolostone with considerable local variations due to the nature of primary bioclastic material (Liberty et al. 1976). A minimum thickness of about 15 m has been recorded in the region (Liberty et al. 1976), with up to 30 m recorded at the highest bluffs in Mono Cliffs Provincial Park (Patten 1973).

In the park, the Amabel Formation is exposed along the almost continuous cliff of the Niagara Escarpment (Figure 11; Site 6, UTM 739787) and the two outliers. It is also exposed in thinly mantled areas behind the brow of the escarpment (Figure 12; Site 7, UTM 736773), including small cliffed valleys away from the escarpment edge, and on top of the outliers, and in scattered, thinly mantled outcrops below the main escarpment face (Site 8, UTM 741783). It is commonly represented by a blocky, dense, medium- to coarse-crystalline, light buff to grey-blue dolostone. The unit is very fossiliferous, with large macrofossils, primarily crinoids and fragmental crinoidal material, commonly visible on weathered surfaces. Vuggy layers and lenses, with vugs often lined with crystals of calcite, are also common throughout the section. Bedding ranges from thick to quite thin, and exhibits a planar to slightly wavy pattern in weathered surfaces.

Despite the abundance of cliff sections, most exposures are poor. Deep talus slopes mantle the basal portions of the cliff face, and a pervasive lichen and moss cover on most exposed rock surfaces mask the nature of the outcrop. Only in some vertical cliff sections, such as opposite both outliers, and on the north face of the southern outlier, is the bedrock surface relatively well-exposed, if somewhat inaccessible. Bedrock is also exposed or only thinly mantled in broad patches adjacent to the brow of the escarpment. Locally-derived rubble (essentially unweathered Amabel dolostones) and ice-contact debris characterize the thin discontinuous sediment cover of these areas, with minor, poor exposures of Amabel dolostone poking through the cover. Good examples of this occur opposite the north outlier (Site 9, UTM 738790; Site 10, UTM 738783), in the southwest corner of the park (Site 11, UTM 743759), and well behind the main escarpment edge south of McCarston's Lake (Site 7). The tops of the outliers are also essentially thinly mantled to bare bedrock plains, though deep weathering of these surfaces prevents good access to fresh bedrock surfaces. A sizable deposit of drift rich in large Amabel blocks occurs on the northwest portion of the north outlier.

The thin-bedded horizons are commonly weathered more deeply than the more massive, blocky horizons, resulting in clefts or crevices incised into vertical cliff exposures. These are particularly well-developed along the central portions of the escarpment exposed in the park. Here the escarpment is notable for deep crevice caves created by the rotation and downslope slumping of huge blocks from the edge of the escarpment (Figure 13). This process and the caves are described in the *Karst Solution and Mass Wasting* section of the report.



Figure 11. Low, partially mantled cliff of the main escarpment, showing weathered Amabel dolostones (Site 6). The cliff in the middle foreground is about 3 m high.



Figure 12. Poorly exposed Amabel dolostones well behind the brow of the main escarpment face (Site 7). Rock hammer (lower right) for scale.



Figure 13. Crevice caves formed at the brow of the escarpment. The base of the 6 m high block in the centre has rotated away from the main cliff, with the canted top forming the roof of the cave.



Figure 14. Small kettle depression in the Orangeville Moraine (Site 15).

b) *Surficial Deposits*

Mono Cliffs Provincial Park is located in an area of confluence between the late glacial Simcoe sublobe (from the northeast) and Georgian Bay lobe (from the northwest) ice. This area of the escarpment, marked by a minor re-entrant valley in which the headwaters of Sheldon Creek now rise, marks the chaotic junction of the deposits of these ice lobes, the Orangeville Interlobate Moraine to the west, above the escarpment, and a complex of the Singhampton-Gibraltar Moraine to the east (the eastern edges of which are in the park). Till fabrics recorded by Gwyn (1975) in the region further clarify the position of confluence of the two ice lobes along the Niagara Escarpment.

Separating these major ice-contact bodies of sediment is the Violet Hill meltwater channel, which drained meltwaters from the north between the Niagara Escarpment and the stagnating ice at the Singhampton-Gibraltar Moraine position (Figure 7). Ice-contact stratified drift is interbedded with glaciofluvial and minor glaciolacustrine sediments within the moraines, while sand and gravel dominate in the flat-bottomed meltwater channels (Gwyn 1975). Glacial striae, reflecting the direction of ice movement, were not noted to occur on the generally weathered bedrock surfaces in the park, though west-flowing indicators are documented just north of the park (Gwyn 1975).

Till Exposures of glacial till in the study area are not common. A single till is recognized. It is a red to red-brown, stony, slightly clayey, silty, fine- to coarse-grained sand in which Paleozoic clast lithologies dominate Precambrian lithologies. The red colour is the result of incorporation of Queenston shale into the till. Clasts are generally small, with pebble and cobble sizes predominating. The Precambrian clasts are generally larger and more rounded, and often exhibit fine striae and faceting. Incorporated material of less red, more gravelly sediment is also noted, often as lenses or draped around larger clasts. The occurrence of the till is usually associated with observed or inferred occurrences of underlying bedrock. An excellent exposure occurs in a roadcut on 3rd Line E.H.S. (Site 12, UTM 752770). This red till may be a correlative of the "Ablation Till" described by Gwyn (1975) and the "Queenston-matrix till" of Burwasser (1974). It was deposited by the Simcoe sublobe (Gwyn 1975).

A diamict (a sediment with unsorted components) with qualities very similar to the till described above was noted to occur in association with ice-contact stratified drift, particularly in the excavated pit face of the Mono Township landfill site (Site 13, UTM 751789). Here it occurs as a light green, crudely bedded, very stony, silty sand with abundant light yellow sandy stringers and red clay rip-ups. A similar sediment occurs in a bank exposure along the Bruce Trail near McCarston's Lake (Site 14, 734779). The unit is interpreted to be a flow till associated with meltout of ablating ice in the moraine zone of deposition.

Orangeville Moraine The western portion of the park is underlain by ice-contact sediments and till related to deposition of the Orangeville Moraine, a large interlobate deposit formed when the Georgian Bay lobe and Simcoe sublobe split during final deglaciation of the region (Gwyn 1972,1975; Patten 1973; Riley 1983) (Warren 1973 classified the ice-contact belt as the Singhampton Moraine). In the study area, the Orangeville Moraine occurs above the Niagara Escarpment. Gwyn (1975) describes the moraine as consisting of medium-grained sand with some gravel, pebbly sand and bouldery sand. Finer sand caps the moraine to a depth of up to several metres. Interbeds of finer material, including very thin red clay drapes and horizons containing small clay rip-ups, attest to quiet periods in the ice-contact environment. Large cobbles and small boulders form most of the oversized material, consisting predominantly of Paleozoic lithologies, reflecting its source in the basin of Georgian Bay. Rounded to subrounded, often striated and faceted, Precambrian (granitic) lithologies also occur but form only a minor component. Till may core the moraine, as it was noted to occur at the base of some deep sections north of the park.

Within the park, the Orangeville Moraine consists of fairly low-relief, hummocky topography, with an abundance of small kettles (Figure 14; Site 15, UTM 731781) and kame hills. The most chaotic topography occurs over the buried re-entrant valley in the Niagara Escarpment, through the west-central portion of the park. Sharp bouldery ridges, with some constituent blocks up to 1 m in diameter and of local lithologies, intervene with sandy low areas devoid of surface clasts (Figure 15; Site 16, UTM 728772). These ridges have been mapped as a separate unit due to their distinct concentration of local Amabel block lithologies. The ridges may represent a local readvance by ice from the east (Dr. W.M. Tovell, personal communication 1991), although they are considered to be part of the Orangeville Moraine.

McCarston's Lake (Site 17, UTM 733778) is centred on this area, being a large water-filled kettle over 9 m deep. Regional evidence suggests that a moraine system of highly localized material crosses the re-entrant here, and numerous other areas of the Niagara Escarpment, blocking drainage by forming a natural dam for McCarston's Lake (Dr. W.M. Tovell, personal communication 1991). The unvegetated slope above the escarpment which at over 500 m elevation forms a prominent lookout on the Bruce Trail (Figures 16,17; Site 18, UTM 736781) may also constitute part of this moraine, consisting of anomalously high volumes of local, generally unmodified Amabel Formation dolostone blocks. This moraine may also occur on top of the north outlier to the east of the lookout.

North and south of the deposits in the bedrock re-entrant, the Orangeville Moraine consists of a more subdued topography, broad hills and swales predominating, grading towards a thin drift mantle at the brow of the escarpment. Road cuts in this portion of the park exhibit generally fine-grained but chaotically bedded sediments, predominantly loose stony sand and possibly flow till units. Fresh exposures are not common in these sediments.

Singhampton-Gibraltar Moraine In the region east of the park, the Singhampton-Gibraltar Moraine complex consists of a very broad highland of ice-contact stratified drift and ice stagnation features such as small kettles, indistinct ridges and fluvial channels, trending parallel to and below the Niagara Escarpment. Here the two moraines, which are recognized to the north and south as separate features (Straw 1968; Burwasser 1974; White 1975), cannot be distinguished morphologically. The complex may represent a single recessional moraine deposited during a long stillstand through Singhampton and Gibraltar time, the result of a local delay in ice retreat from this higher section of the Ontario uplands (Riley 1983). A slightly higher elevation along the western portion of the zone (Singhampton Moraine?) may signify a subtle two-part retreat of ice in the area while adjacent areas were deglaciated more vigorously (Riley 1983). The moraine complex represents the first deposits of the waning Simcoe sublobe of the Port Bruce ice sheet.

Only a small portion along the western edge of the Singhampton-Gibraltar Moraine is located within Mono Cliffs Provincial Park. Here it consists of a fairly low, locally hummocky terrain punctuated by small kettles and kame hills. Constituent materials are generally stratified and fine-grained, being pebbly sands and fine gravels, with few large clasts. The clasts tend to be a mix of Precambrian and Paleozoic lithologies, attesting to the Simcoe basin origin of these deposits. Riley (1983) noted local concentrations of Precambrian clast lithologies in the moraine complex south of Rellesey, east of the park. The chaotic nature of these ice-contact sediments are well-exposed in the Mono Township landfill just outside the northeast corner of the park (Site 13). The deepest sediments in the study area constitute part of this moraine, being over 30 m deep in the east-central portion of the park (Gwyn and Frazer 1975).

The moraine complex partially buries the southern portion of the southern outlier in the park. Hummocky topography, smoothed and capped by glaciofluvial sand and fine gravel, define this deposit, although definitive boundaries are difficult to map due to the modifications made by the meltwaters.



Figure 15. Kame ridges, punctuated by large clasts of Amabel dolostone, with intervening depressions devoid of surface clasts (Site 16).

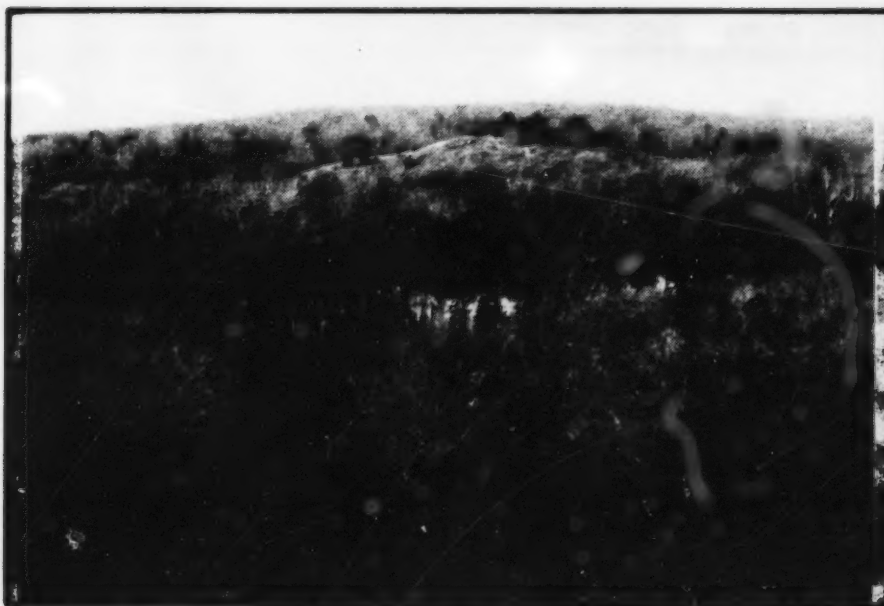


Figure 16. Orangeville Moraine above the brow of the escarpment. The moraine here forms one of the highest points in the park; the Bruce Trail passes over the hill for a magnificent view over the surrounding area below the escarpment.



Figure 17. View of the south outlier and Violet Hill meltwater channel from the Bruce Trail lookout on the Orangeville Moraine above the main escarpment face (Site 18).



Figure 18. Channel remnant on glacial deposit adjacent to the main escarpment face between the north outlier and the escarpment (Site 19).

Violet Hill Meltwater Channel The Violet Hill meltwater channel (Lavender-Violet Hill Meltwater Channel of Gwyn 1975) originates south of Singhampton, north of the study area, and was one of the first conduits to drain meltwaters along the developing seam between the Georgian Bay lobe and the Simcoe sublobe, southward to possibly as far as glacial Lake Arkona (in the Erie basin). It was generally confined by the Niagara Escarpment (or the deposits of the Orangeville Moraine above the escarpment) to the west, and the ice front, marked first by the Singhampton Moraine and then the Gibraltar Moraine, to the east (Gwyn 1975; Riley 1983).

In the immediate study area, the Violet Hill meltwater channel can be traced as it emerges from a bedrock gorge near Black Bank to the north, crosses a deltaic deposit at the base of the escarpment, follows the escarpment edge through Kilgorie and Violet Hill (its "type" area due to the excellent definition and exposure here), and southward past Mono Cliffs Provincial Park and Mono Centre (Gwyn 1975) to the upper Nottawasaga River and Orangeville area (Figure 7) (Riley 1983; Kor, in prep.). The fact that preglacial and postglacial drainage in the region is to the east indicates that immediate postglacial drainage through the meltwater channel was dammed by ice occupying the Singhampton-Gibraltar Moraine system position and the Orangeville re-entrant valley. Substantial thicknesses of glaciofluvial sediment, from 15-60 m, are recorded in the channel (Gwyn 1975).

The bed of the upper (northern) portion of the meltwater channel in this region is situated at an elevation of about 435 m asl. In the park this level is represented by the majority of the surficial sediment below the escarpment. No extraction pits occur near the park to provide a three dimensional view of the constituent deposits, but north of the park, at Violet Hill, several gravel pits reveal a minimum of 8 m of planar to low-angle, gravelly channel deposits with strong southward paleoflow direction indicators (Kor, in prep.). Minor clay drapes and lenses, and occasional lonestone debris (single occurrences of large clasts), indicative of iceberg-rafting, suggests that ice-contact conditions still prevailed during the operation of the meltwater channel. Thick sand units often show soft sediment deformation structures, such as ball-and-pillow and faulting, suggesting rapid burial of water-saturated sediment by subsequent deposits. A general coarsening upward sequence in the vertical exposures suggest that the meltwater channel became more shallow with time. Sand and fine gravel constitute the surface sediment of this deposit.

The 435 m channel level constitutes a flat to gently rolling terrain below the escarpment, east of both outliers and between the southern outlier and the main escarpment face. East of the southern outlier, the bed of the channel at this elevation also constitutes the Whirlpool-Manitoulin bedrock secondary scarp. Its definition is lost somewhat south and east of the south outlier, where hummocky topography of the Singhampton-Gibraltar Moraine complex, which partially buries the outlier here, has been modified by meltwaters. Without adequate vertical sections to study in the vicinity, boundaries in this area are difficult to define. The banks of the high-level channel are well defined by the talus slopes adjacent to the escarpment and by the hummocky terrain of the Singhampton-Gibraltar Moraine complex.

Between the north outlier and the main escarpment face removal of glacial debris by the meltwater channel flow was incomplete. A complex morphology of abandoned channels and pools (Figure 18; Site 19, UTM 740786) within the valley suggests that water flow through here was chaotic, but did not last long enough to effect removal of sediment to the common level of the rest of the channel. The deepest channel remnants occur adjacent to the bedrock walls of the main escarpment face. A low terrace at the north end of the narrow valley suggests that meltwaters quickly abandoned this route in favour of the 435 m level around the east side of the north outlier.

A lower meltwater channel level occurs incised into, and usually to the east of, the higher level. This level, at an elevation of about 400 m asl, occurs from the "type" area at Violet Hill (Kor, in prep.) southward to Orangeville. The meltwaters which used this channel may have originated west of the Orangeville Moraine at Primrose. At that locality meltwaters may have spilled across the moraine along the present Boyne River valley. It then encountered the Gibraltar ice and was diverted southward along the higher level meltwater

channel and incised it. In Mono Cliffs Provincial Park, this lower level occurs east of the south outlier, where it rejoins the level channel after a large meander around a portion of the Singhampton-Gibraltar Moraine, informally known as the Elder branch (Figure 6c). Here it consists of a flat-bottomed channel of generally swampy conditions trending northwest-southeast (Figure 19; Site 20, centred on UTM 751769). Distinct, incised banks mark its course southward along the edge of the Singhampton-Gibraltar Moraine outside the park.

In the park, the banks of the lower channel level are well defined by the bluffs cut into the Whirlpool-Manitoulin scarp and the edge of the Singhampton-Gibraltar Moraine complex. Few fresh exposures in the deposits of this lower level occur, but generally sediments are finer grained than in the upper level terraces. Gwyn (1975) noted that the material in this lower level channel consists generally of medium-grained silty sand and pebbly sand with minor veneers of sandy pebbly gravel. The extent and location of the lower channel indicates that it represents a later phase of the Violet Hill meltwater channel, probably when the ice front retreated from the Singhampton to the Gibraltar Moraine positions. The lower channel segment probably enhanced pre-existing lows in the underlying Queenston Formation topography.

The term 'meltwater channel' is preferred over the misused term 'spillway'. The former refers to any conduit adjacent to or near glacial ice which carried its meltwater away from the zone of melting. 'Spillway' usually refers only to a conduit used by glacial meltwaters to drain a glacial lake. In the case of the Violet Hill meltwater channel, glacial lakes were not directly involved in the ice-contact system, although local pondings doubtlessly occurred, particularly in the Hockley valley (Riley 1983).

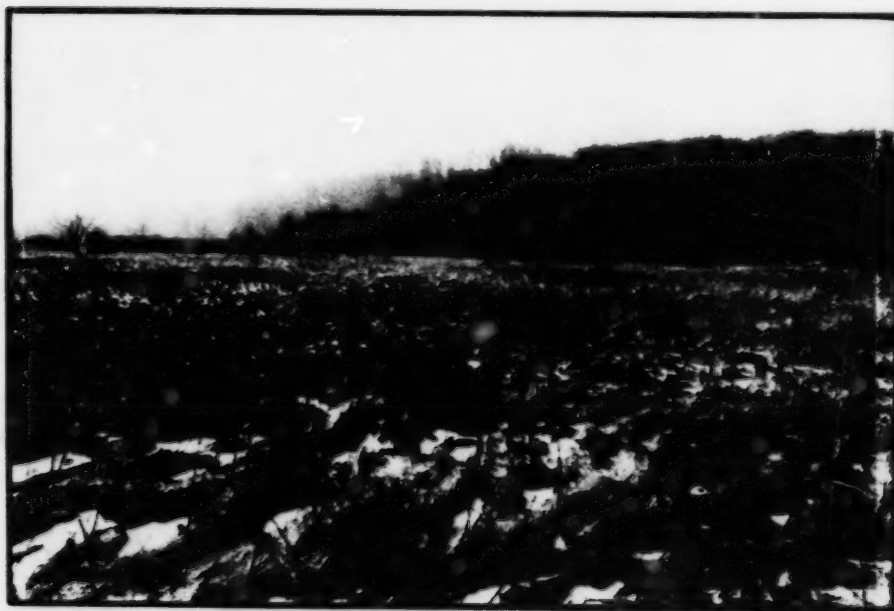


Figure 19. Lower level of the Violet Hill meltwater channel below the secondary Whirlpool-Manitoulin scarp (Site 20).

c) *Karst Solution and Mass Wasting*

Features of karst solution and mass wasting are discussed together in this section due to their association in creating the morphology at the edge of the exposed portions of the escarpment. It is the weakening by karst solution along structural elements in the dolostone caprock at the edge of the escarpment that helped to create the conditions for the downslope slumping and rockfalls manifest as crevice caves and talus slopes in the park area.

Features related to karst solution and mass wasting are well developed in Mono Cliffs Provincial Park. Karst features, the result of chemical solution of the carbonate bedrock of the Amabel Formation, consist predominantly of minor surface forms referred to collectively as 'karren' (Cowell 1974). Karst solution along joints and cracks in the dolostone promote mass wasting processes and contribute to the formation of crevice cave systems at the edge of the escarpment. Mass wasting processes are also highlighted in the massive slopes of talus at the base of most of the exposed escarpment cliffs. Due to the biological significance and sensitivity of a number of these sites (Lindsay 1991), the exact location of some features will not be given in this report; they are on file at the offices of the Ontario Ministry of Natural Resources, Parks and Recreational Areas Section, Southern Region, Aurora.

Block fracture and fissure systems, also known as crevice caves, are well developed at a number of locations at the brow of the exposed escarpment in the park, particularly on the north face of the predominantly buried re-entrant valley and on the east side of the north outlier. They illustrate the processes which maintain the vertical character of the cliff face of the escarpment. This involves the erosion or removal of the relatively soft shales of the Cabot Head Formation (not exposed in the park) from below the more resistant Amabel Formation dolostones. This resulted in destabilization of the Amabel cap, which separated along vertical jointing planes already weakened by solution weathering. These blocks now form part of the talus slope below the cliff face. It is likely that glacial meltwaters flowing along the cliff face, after cutting through the mantle of glacial debris to the cliff face, helped to erode the Cabot Head Formation shale.

Larger masses lean away from the cliff face forming narrow fissures. Two or three such parallel systems are developed in places along the brow of the escarpment. With time, as the blocks rotate further from the escarpment edge on the shale substrate, the fissures widen and deepen, forming the characteristic crevice caves. These range from 2-8 m wide and 2-30 m deep. Under some conditions, as large blocks slip downslope on the groundwater-charged shales, they tip backwards, creating roofed crevice systems near the edge of the escarpment. One such system, known locally as Elba Cave (Figure 20), is located along the western side of the north outlier. The cave system is entered through a single, very small opening along an indistinct seam which marks the roof of the cave.

The remains of at least 13 types of mammals have been recovered from the fissure systems in the park (Lindsay 1991). Two of these, marten and pika, are significant in that they represent species either not occurring in the area since probably the early Holocene (pika) or in several centuries (marten).

Mass wasting processes in the park are highlighted by the talus slopes which line essentially the whole length of the exposed cliff face of the escarpment. These lie at various angles of repose, dependant largely on the size of the constituent material. Slopes composed of larger blocks are generally steeper than those composed of finer material and generally occupy positions below the highest cliff faces. All talus in the park was observed to consist of Amabel Formation dolostone.

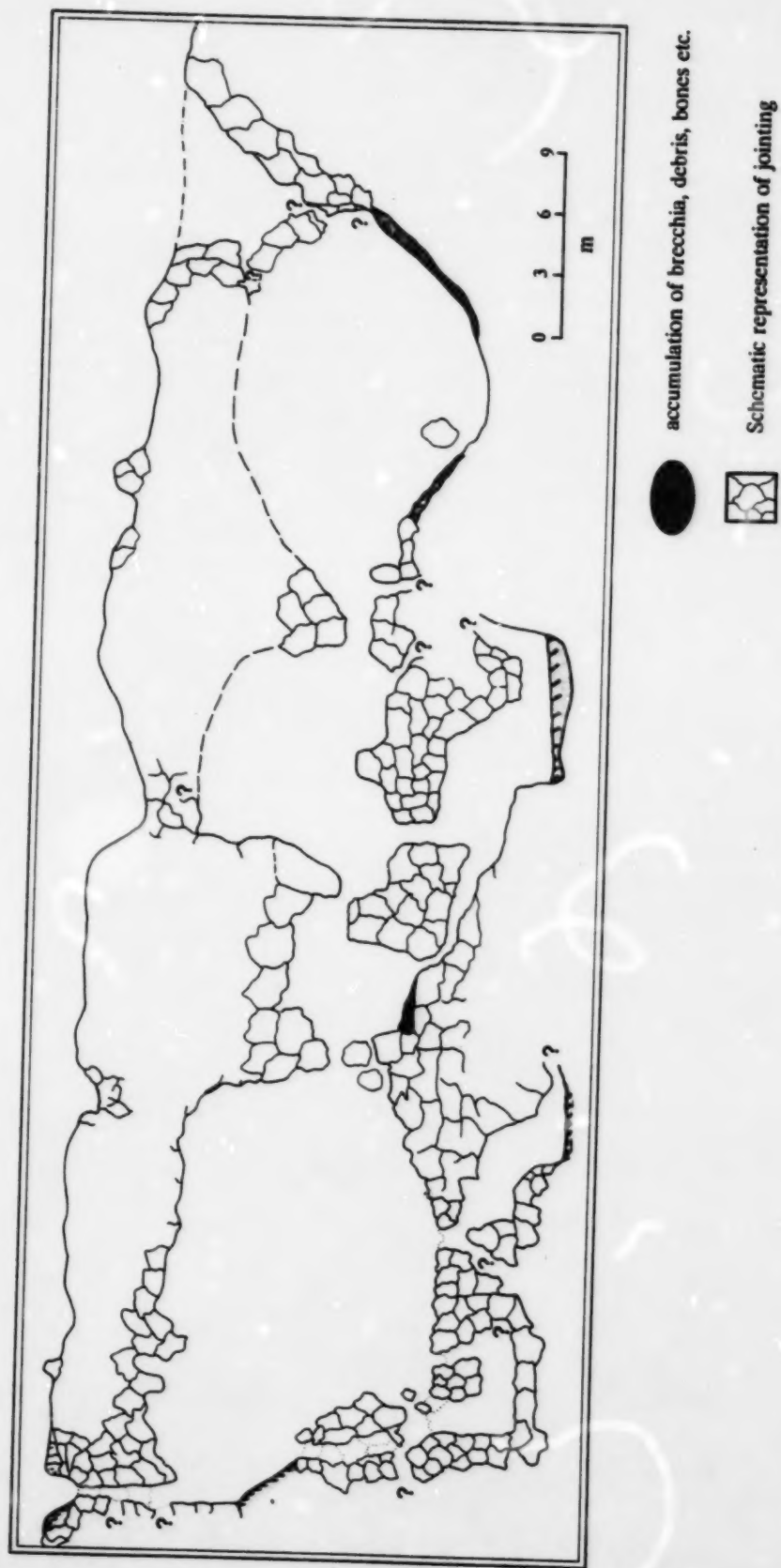


Figure 20. Schematic cross-section of the Elba Cave system. (J.L. Riley, 29 Sept. 1990)

2.3 Economic Geology

Some units of the bedrock of the Niagara Escarpment have been used regionally as a source of crushable aggregate and building stone. Generally this source constitutes the lowest units (Queenston shale, Whirlpool sandstone) and highest units (Amabel and Lockport limestone and dolostone) of the sequence. In the region of the park, the Niagara Escarpment is generally drift covered and quarrying of these units has traditionally not occurred. The exposed to thin drift areas of Amabel dolostones within and near the park however, are considered to be of good quality and may represent a viable economic source of crushable aggregate (Ontario Geological Survey 1979). Similarly, the near-surface exposure of the Queenston Formation shale in Mono Township is considered to have potential value as a clay source (Ontario Geological Survey 1979). The Whirlpool and Manitoulin Formations, traditionally exploited elsewhere along the escarpment for building stone, are not considered to be economically viable in Mono Township due to their restricted exposure.

The surficial sediment within and adjacent to the park is generally unsuitable as a quality aggregate source despite its great thickness and volume in Mono Township. The Ontario Geological Survey (1979) indicated that although most of the study area is underlain by considerable thicknesses of ice-contact and glaciofluvial (outwash) sand and gravel, the quality of these deposits is constrained by topography, height of the water table, and deposit geometry. The quality of the deposits is also affected by large volumes of fine material, low gravel content, great textural variety, low amounts of crushable aggregate, and deleterious constituents. No active borrow pits occur in or near the park, although the Mono Township landfill site is situated in an old borrow pit.

Mono Cliffs Provincial Park lies within the Niagara Escarpment Plan area and is subject to its zoning restrictions. A large portion of the park, essentially all exposed bedrock areas, the McCarston's Lake watershed, the outliers and most of the meltwater channel deposits are zoned "Escarpment Natural", which provide that economically viable resources within the zone are not available for extraction. Proposed zoning of this area as a "Nature Reserve" (see Chapter 3.2.a) also provides for no impact by man on the area. In the Niagara Escarpment Plan area, most of the rest of the park is zoned "Escarpment Protection", with only a fringe at the western edge, consisting of old fields, zoned as "Escarpment Rural".

CHAPTER 3. PLANNING CONSIDERATIONS

3.1 Significant Features

Mono Cliffs Provincial Park is recognized as a highly significant natural area with impressive scenic values primarily due to its outstanding geology. The park has especially good exposures of a portion of the Niagara Escarpment in a region where it is more typically buried by a deep mantle of glacial sediments. Exposure of the escarpment between Credit Forks and Lavender Falls is not common, and none match the Mono Cliffs area in extent, configuration or associated escarpment features. Early postglacial meltwaters cut through the sediment cover in this area to expose deep sections through the escarpment, from the Amabel caprock down to the Queenston shale basement rock, in cliffs over 30 m high. An excellent example of the secondary scarp formed below the Amabel bluff by the combined Whirlpool and Manitoulin Formations was also exploited by the meltwater channel through the park.

The pristine nature and excellent development of two outliers adjacent to the main escarpment face is considered to be provincially significant (Woerns 1977). Outliers are uncommon along the southern portions of the escarpment, and their occurrence in the Mono Cliffs area is particularly fine, having high interpretive, educational and scenic value.

Features related to karst solution and mass wasting processes, including crevice cave systems and massive slopes of block talus, are well developed at the brow of the escarpment and its outliers within the park. These are regionally significant, enhancing greatly the interpretive values of the park.

The Orangeville Moraine marks the seam between two late glacial ice lobes; its hummocky kame and kettle topography is well-developed in the park. The moraine area is relatively undisturbed and occupies the headwaters of a branch of Sheldon Creek. Of note in this area is McCarston's Lake, a large water-filled kettle. Ongoing analysis of the bottom sediments of this lake are yielding a comprehensive postglacial vegetation and climatic record of the region. The undisturbed nature of the watershed in this area is uncommon to the escarpment and makes this analysis possible and significant. Representation of the Orangeville Moraine in Mono Cliffs Provincial Park complements its occurrence in the Violet Hill Channel-Boyne Valley ANSI.

The Violet Hill meltwater channel occupies the low terrain below the escarpment face, defining the first ice-free zone between the Georgian Bay and Simcoe ice lobes during early deglaciation of the region. The meltwater channel excavated the Niagara Escarpment and probably served to erode the relatively soft shales beneath the Amabel dolomite, which served to enhance the vertical contours of this portion of the escarpment and the formation of the crevice cave systems for which the park is known. The meltwaters also excavated the narrow canyon between the southern outlier and the main escarpment face to its main level, having failed to do so between the northern outlier and the escarpment face.

The Violet Hill meltwater channel is significant in carrying some of the first meltwaters from the retreating Port Bruce ice, and helped define the emerging "Ontario Island". At least two periods of flow are indicated by two distinct flat-bottomed channel segments in the park, defined by adjacent banks of glaciofluvial sediment. The meltwater channel is here near its "type" area at Violet Hill, in the Violet Hill Channel-Boyne Valley ANSI to the north. Its occurrence in the park, where its passage coincided with the escarpment, complements the occurrence of the meltwater channel to the north, where its passage was not confined by bedrock topography.

3.2 Recommendations

a) *Boundaries and Zoning*

Mono Cliffs Provincial Park, defined in the 1974 Park Master Plan, incorporates a varied landscape of glacial and postglacial sediments deposited at the edge of an exposed portion of the Niagara Escarpment. The Master Plan defined a core "Natural Zone" which outlined most of the significant geological features. In subsequent studies (Woerns 1977; 1988 Mapping of Conservation Lands), the area of identified earth science ANSI significance was modified, corresponding more or less with the designated "Escarpment Natural" lands of the park (Niagara Escarpment Plan 1985). Much of this area has been retained here, including the significant features described above, and are recommended to be redefined as a "Nature Reserve" zone of present terminology (Figure 21), which provides adequate protection to the geological elements. Nature reserve zoning would not exclude the retention and further development of the trail system through the park, but encourage the appropriate management, signage, and interpretation of the significant features of the park. A trail system incorporating numbered stations described in self-guiding information leaflets would be one of the appropriate vehicles for the interpretation of the earth science features of the park.

b) *Land Uses*

The major land uses within the park at present are low-impact activities, primarily hiking, skiing, organized outdoor education, and nature viewing. Natural forest environments occur on the uplands in the headwaters area of Sheldon Creek and in lowland areas adjacent to the escarpment face. The area surrounding the park is sparsely farmed. These activities presently have minimal impact on the geological components of the ANSI described in the present report.

Of greater consequence are rock climbing and spelunking activities in the park. These low-volume but concentrated activities degrade specific portions of the cliff face and in particular the crevice cave systems. Delicate speleological features, significant animal remains and special vegetation attributes all suffer from overuse by these activities. It is recommended that spelunking in Elba Cave be controlled through the use of permits and an entrance grate to prevent unauthorized access. Rock climbing should be reconsidered in the park context, to encourage the use of alternate sites outside the park. If limited climbing without damage to the cliffs is considered possible, the Jacob's Ladder area opposite the south outlier, already heavily impacted, would be a possible location for localizing such activities in the park, although it is within the Nature Reserve zone recommended above.

Future development of facilities in the park should be directed to those areas within the park outside the nature reserve zone. The best location for such facilities in this case is probably the lower segment of the Violet Hill meltwater channel (development zone boundary, Figure 21), which is presently under pasture. Some of the most impressive and panoramic views of the escarpment features of the park are from this area, thus providing the visitor with a dramatic introduction to the physical setting of the park and the region.

One of the objectives of the provincial parks programme is to provide for the dissemination of natural history information to the public. This may be done through a system of nodal parks in which information is presented by displays and written documentation. These nodal parks may contain trail systems which highlight the information presented by the visual and written documentation. The nodal parks may also form destination points for an auto-accessible system of routes highlighting a particular component of the natural history of the region. In Wisconsin, the glacial history of the state is showcased in a comprehensive system of auto routes, hiking trails and nodal parks called the Ice Age Trail. It joins major components of the glacial environment, such as eskers, moraines and meltwater channels, through a connected system of

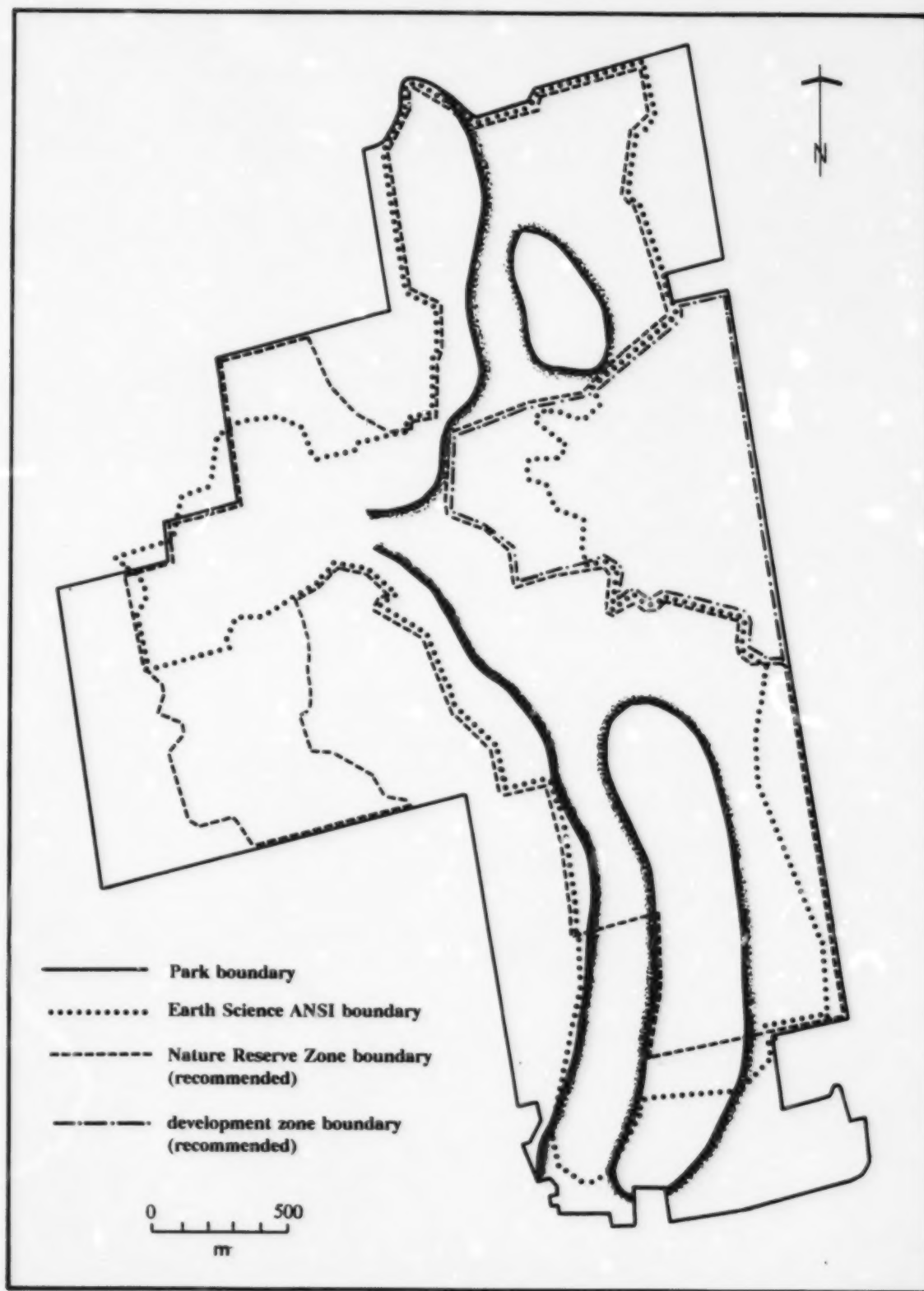


Figure 21. Boundaries and zoning recommendations, Mono Cliffs Provincial Park.

locations where specific and regional information is presented to the visitor. As all of Ontario was completely covered by the glaciers of the Late Wisconsinan glaciation, and its physical landscape is a direct reflection of these events, a system of parks, auto routes and hiking trails highlighting the glacial events of the province similar to the Wisconsin example should be considered in future planning programmes. Mono Cliffs Provincial Park is ideally located to form a major node in such a system.

c) Other Environmental Considerations

The recommended earth science nature reserve zones are roughly coincident with recommended life science nature reserve zones identified by Lindsay (1991). This coincidence of both earth and life science values enhances the natural values of both of these significant attributes of the park.

3.3 Conclusions

Mono Cliffs Provincial Park is a provincially significant geological site because of its outstanding representation of a complex and diverse glacial landscape formed primarily during the Port Bruce Stadial, during which time key geomorphological processes excavated one of the most significant portions of the Niagara Escarpment through its central zone. The geological values of the study area are summarized as follows:

- 1) Provincially significant representation of bedrock outliers; here these are exceptionally well-developed as a result of glaciofluvial flushing of intervening sediments. Their relatively small size, and their excellent exposure by the clearing of the surrounding land provides for ready association with the main escarpment face and the processes involved in their formation;
- 2) Significant development of a gap in the pervasive sediment cover of the Niagara Escarpment through its central portion; a number of geomorphological processes, including ice-marginal glacial deposition, glaciofluvial erosion, karst solution and mass wasting, are associated with the exhumation of the escarpment in the Mono Cliffs area and are highly interpretable. The complex of bedrock, glacial and postglacial features here make Mono Cliffs Provincial Park a regional node of some significance to the interpretation of the Niagara Escarpment.
- 3) Representation of the Violet Hill meltwater channel and the Orangeville Moraine in the park complements the provincial representation made of these features in the Violet Hill Channel-Boyne Valley ANSI to the north.
- 4) The organic sediments at the bottom of McCarston's Lake are the subject of ongoing research into the postglacial environment of the region due in part to its relative lack of disturbance from cultural activities.
- 5) The combination of pristine forested uplands and cultivated lowland areas provide high scenic and aesthetic values to the park area, in addition to making interpretation of the physical setting a relatively simple task.

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AIR PHOTOS

year	roll	line	numbers
1978	93	4403	115-118
1978	122	4404	122-125
1978	122	4405	203-205

NIAGARA ESCARPMENT INVENTORY PROJECT - EARTH SCIENCE CHECKSHEET

NAME Mono Cliffs Provincial Park		OEM MAP NUMBER 5700 48750 5750 48750		NTS MAP NUMBER 41 A/1	UTM REFERENCE 745775		
COUNTY Dufferin		1:250,000 NTS MAP SHOWING AREA BOUNDARIES					
TOWNSHIP Mono							
LAT. 44°03'N	LONG. 80° 04'W					AREA 730 ha	ALTITUDE (MIN/MAX) 400 m 520 m
OWNERSHIP Ministry of Natural Resources							
MNR REGION & DISTRICT Southern/Midhurst						CONSERVATION AUTHORITY	
AERIAL PHOTOGRAPHS - BASEMAPS							
YEAR	ROLL	FLIGHT LINE	NUMBERS				
1978	93	4403	115-118				
	122	4404	122-125				
	122	4405	203-205				
EARTH SCIENCE FEATURES Mono Cliffs Provincial Park incorporates an unusually well-exposed portion of the central Niagara Escarpment area. High vertical bluffs of the Silurian Amabel Formation dolostones of the main escarpment face overlook a strong secondary scarp of poorly exposed Manitoulin and Whirlpool Formation sediments, as well as a number of exposures of the underlying Ordovician Queenston Formation shale. The exposed cliffs, almost 30 m high in places, exhibit crevice caves, and their lower portions are mantled by massive talus slopes. Two lozenge-shaped outliers parallel the escarpment edge, the result of differential erosion of surrounding rock. The northern outlier particularly displays deep crevice caves. The two outliers flank a re-entrant valley which locally breaches the escarpment face and is predominantly mantled in glacial drift. Above the escarpment is the hummocky kame and kettle topography of the Orangeville Moraine. One large water-filled kettle, McCarston's Lake, contains an extensive post-glacial organic record. Below the escarpment, at the eastern edge of the park, a low hummocky topography defines the position of the Singhampton-Gibraltar Moraine. Immediately below the escarpment, a gently rolling to flat topography is attributed to two levels of the Violet Hill meltwater channel which drained glacial meltwaters from areas to the north, along and between the Niagara Escarpment and the ice front, which stood at the Singhampton-Gibraltar Moraine complex immediately to the east. ...cont'd							
SIGNIFICANCE AND SENSITIVITY The park was identified as having <u>provincially significant</u> earth science representation of the outliers associated with the Niagara Escarpment. Also significant are the portion of the Orangeville Moraine and the Violet Hill meltwater channel represented in the park. Of particular significance is McCarston's Lake and its immediate vicinity, notable for an extensive and scientifically interesting organic record. Two levels of the Violet Hill spillway are represented, the result of two periods of use by glacial meltwater flow. ...cont'd							
MAJOR INFORMATION SOURCES Gwyn, Q.H.J. 1975. Quaternary Geology of the Dundalk Area, Southern Ontario; Ontario Division of Mines, Open File Report 5132, 120p. Liberty, B.A., Bond, I.J. and Telford, P.G. 1976. Paleozoic Geology, Dundalk, Southern Ontario; Ontario Division of Mines, Map 2340, scale 1:50,000. Riley, J.L. 1983. Quaternary Geology of the Mono Township Area, Dufferin County, Southern Ontario; unpublished document, Q.M.N.R. Parks & Recreational Areas, Southern Region, Aurora, Ontario. 13p.							
DATE COMPILED November 1991		COMPILED BY P. Kor					

EARTH SCIENCE FEATURES (cont'd)

The upper (older) meltwater channel level was responsible for removing glacial sediment adjacent to the escarpment and exposing the rock cliffs evident in the park. It also partially excavated glacial sediment between the two outliers and the main escarpment face. The lower (younger) channel level illustrates a slight widening of the channel to the east. The meltwater channel may have indirectly contributed to the formation of extensive crevice systems in the park by clearing and defining cliff edges, thereby undermining them by exposing the softer sediments underlying the Amabel.

SIGNIFICANCE AND SENSITIVITY (cont'd)

Present levels of development and use do not pose a threat to the integrity of the geological features of the park. The extreme sensitivity of the life science values associated with the crevice caves precludes the presentation here of their exact location. Potential future development of park facilities are recommended to be placed on the level ground of the Violet Hill meltwater channel in the east-central portions of the park.



GEOLOGY OF PROVINCE

MA

RECENT

7

CULTURAL FEATURE

6

SWAMP DEPOSITS

PLEISTOCENE

5

TALUS: large block
slopes

4

GLACIOFLUVIAL DEPOSITS

3

ICE-CONTACT DEPOSITS

3a

Orangeville

3b

late-stage
in local bed

3c

Singhampton

3d

moraine material
by glaciofluvial

2

BEDROCK-DRIFT

2a

discontinuous

2b

steep slopes

SILURIAN-ORDOVICIAN

1

BARE BEDROCK:

1a

Amabel Formation



GEOLOGY OF MONO CLIFFS PROVINCIAL PARK

MAP 1

RECENT

7

CULTURAL FEATURES: extensively modified by man

6

SWAMP DEPOSITS AND ALLUVIUM: muck, silt, sand

PLEISTOCENE

5

TALUS: large blocks Amabel Formation; steep-angle slopes

4

GLACIOFLUVIAL DEPOSITS: sand and fine gravel

3

ICE-CONTACT DEPOSITS: stratified to massive sand and gravel with minor till

3a

Orangeville Moraine

3b

late-stage moraine deposit (re-advance?) high in local bedrock content (large Amabel Fm. blocks)

3c

Singhampton-Gibraltar Moraine

3d

moraine modified by glaciofluvial action; covered by glaciofluvial sand

2

BEDROCK-DRIFT COMPLEX: ice-contact and glaciofluvial sand and gravel usually < 1m deep

2a

discontinuous, patchy cover with numerous protruding rock knobs.

2b

steep slopes of locally-derived Whirlpool Formation rubble.

SILURIAN-ORDOVICIAN

1

BARE BEDROCK: vertical cliffs and secondary scarp

1a

Amabel Fm (Middle Silurian)



1

SILURIAN-ORDOVICIAN

BARE BEDROCK: v

- 1a Anabel Fm (l)
- 1b Whirlpool Fm
- 1c Queenston Fr



closed depression



ice-contact slope



meltwater channel bank

Scale 1:10,000



Contour Interval 5 Metres





- 2a discontinuous, patchy cover with numerous protruding rock knobs.
2b steep slopes of locally-derived Whirlpool Formation rubble.

SILURIAN-ORDOVICIAN

1

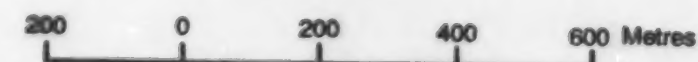
BARE BEDROCK: vertical cliffs and secondary scarp

- 1a Amabel Fm (Middle Silurian)
1b Whirlpool Fm (Lower Silurian)
1c Queenston Fm (Ordovician)



closed depression
ice-contact slope
meltwater channel bank

Scale 1:10,000



Contour Interval 5 Metres



Map 1: Kor, P.S.G. 1991
An Earth Science Inventory and Evaluation of
Mono Cliffs Provincial Park,
Ontario Ministry of Natural Resources,
Southern Region, Aurora.
Base map is a composite of the following OMR
map sheets, based on 1979 aerial photography:
10 17 5708 48750
10 17 5790 48750
Compilation and design by P.Kor and M.McLennan.
Cartography by S.Smith November 1991.